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JOURNAL OF ECONOMIC ENTOMOLOGY

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Forecasting Hatching Levels of the European Corn Borer

JOHN HAWKINS and J. J. DEVITT,[1] *Maine Agricultural Experiment Station, Orono*

Field examination of corn in order to estimate the relative abundance of egg masses has been used as a basis for timing the insecticidal applications for the European corn borer and to determine which fields to treat. This practice has not proven entirely satisfactory for Maine corn growers due to the fact that even where no eggs were found borer infestations were later discovered.

Accurate timing in the application of insecticides for the European corn borer has been emphasized in some of the recent publications. "Correct timing is essential in chemical control of the borer" is a statement made by Holdaway *et al.* (1949). "Apply insecticides when 70 per cent of the eggs have hatched" is the recommendation of Decker & Apple (1949). "Control of approximately 85 per cent of the borers was obtained by a single application of DDT spray when applied at the time when a hatching level of 52 per cent had been reached" (Hawkins 1951).

Certain corn growth stages are especially favorable to European corn borer survival according to Baird (1943) and Batchelder (1949). Ditman & Lloyd (1951) state that there appeared to be a definite relationship between development of the corn plant and the best time of treatment, and that the "highest reduction of larvae in ears with a single spray was generally obtained during the early silk stage." Data from experimental corn plots maintained during the past three seasons at Newport, Maine, indicate that corn in growth stages between the late whorl and early silk support the largest European corn borer populations, and that corn growth stages from midgreen tassel to late silk are especially favorable to high percentage establishment by the European corn borer larvae. Consequently, if forecasts can be made of the time of hatching levels of dangerous proportions and if they are coincident with susceptible corn growth stages, it would be possible to restrict control activities to such areas as are most seriously threatened by the borers. Another advantage of forecasting hatching levels is that preparations could be made in advance for treatments when the crop is likely to be in the greatest danger and at the time when insecticides are most effective.

Lathrop & Dirks (1945), in timing the emergence of the apple fruit fly, show that phenological data can be used in forecasting when given levels of emergence can be expected. Observations by the present authors, prior to 1950, showed that cumulative mean temperatures were useful for forecasting the hatching levels of the European corn borer eggs. During 1950 and 1951 the project was enlarged to obtain more extensive data. Results are included from data obtained during the 6-year period 1946–51. Forecasts are now being put to practical use by corn growers in timing European corn borer insecticide applications in Maine.

SOURCES OF DATA.—The data on the emergence of the moths were obtained from large rearing cages located adjacent to the Maine Agricultural Experiment Station field laboratory at Newport, Maine. Corn stubble infested with overwintered larvae and pupae mostly of the univoltine strain was gathered each spring from farms in the vicinity of Newport and was spread out on the ground in the cages. As the moths emerged during the season, they were removed twice daily. During the six-years the larvae

[1] Acknowledgment is due to Lawrence A. Potter, who served as a summer assistant during 1949 and 1950 and made valuable contributions to the project.

Eastern Branch.

from 11,301 moths were included in the study.

The oviposition cages used were patterned after those described by Vance & Painter (1946). As they emerged, 25 moths were placed in each cage. Oviposition was confined almost entirely to paper which was placed in the cages. The paper was then removed and renewed each morning. Approximately one-square-inch sections, each containing an egg mass, were cut from the paper. The sections were pinned on the day of oviposition to the undersides of corn leaves. The egg masses were examined daily in order to determine the day of hatching. From 1947 to 1951 inclusive, a total of 41,565 masses of eggs were produced for artificial infestation of the corn in the plots. The data for 1946 were based on naturally infested plants.

The weather statistics were from U. S. Weather Bureau records, compiled by the official station at Winslow, Maine.

Forecasting 5 per cent egg hatch is based on the premise that if a number of insecticide applications are to be made the 5 per cent level would be the lowest at which first applications would be practical.

Two levels of moth emergence were employed with the date when 5 per cent of the moths emerged as a basis for forecasting hatching levels. The first is based on 0.05 per cent emergence, and the second on the emergence of 5 per cent of the moths. The third basis is the sum of daily mean temperatures from April 11 to the date of 5 per cent moth emergence and the number of days from 5 per cent moth emergence to a given hatching level. The data were in each case plotted, and regression lines were calculated.

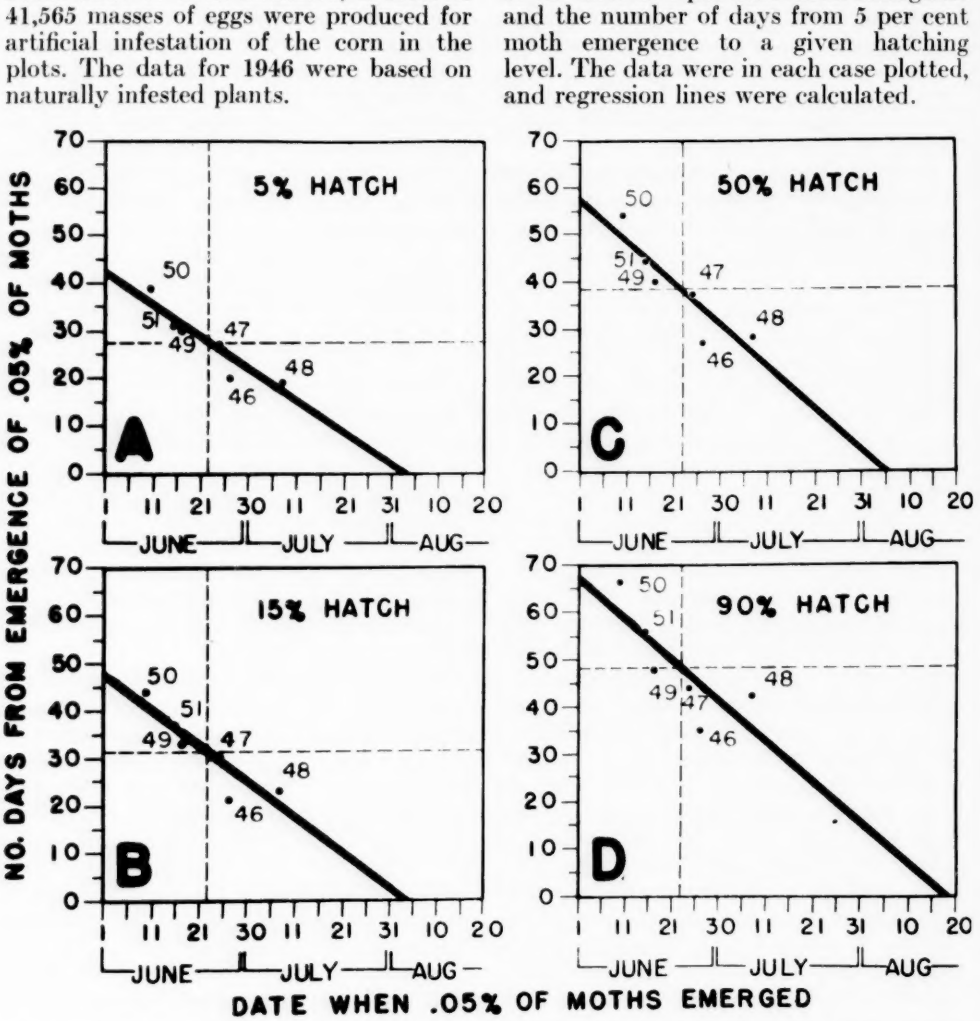

FIG. 1.—Date of emergence of .05 per cent of the moths in relation to hatching levels of the European corn borer. In figures 1 to 3, the heavy bars represent the regression lines, the broken lines represent means, and each point locates the data for each year.

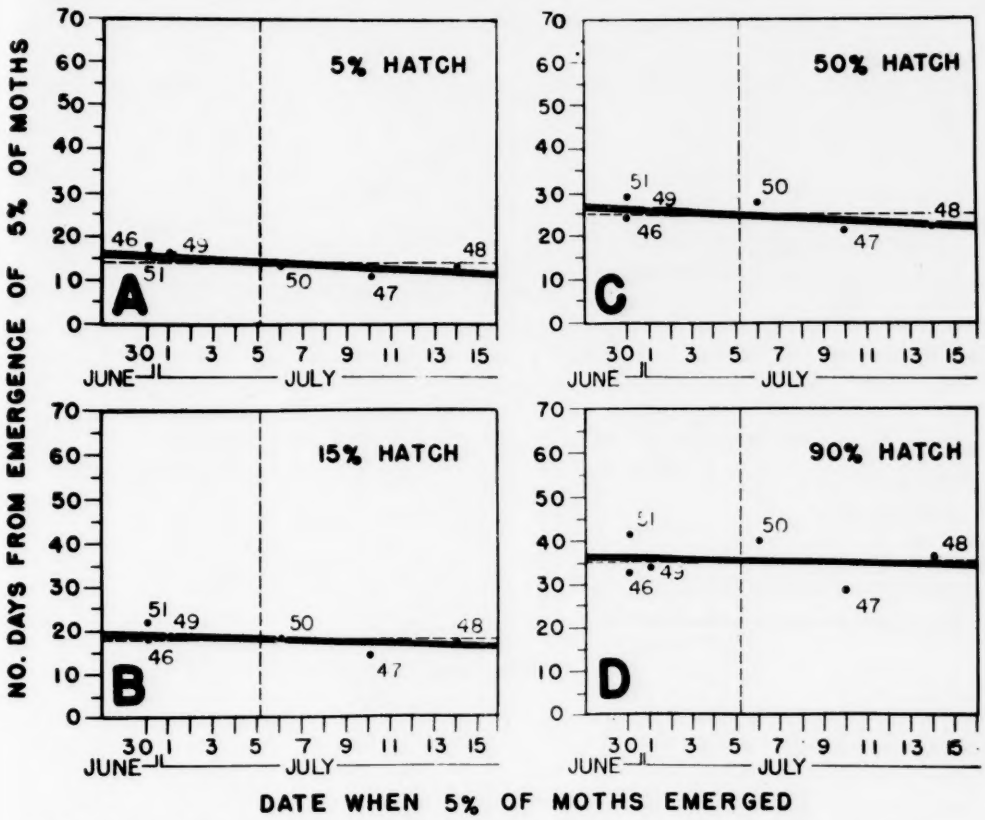

FIG. 2.—Date of emergence of 5 per cent of the moths in relation to hatching levels of the corn borer.

Table 1.—Computation of formulae from emergence of 0.05 per cent of moths.

Year	X Emergence Date	Number Days from 0.05% Moth Emergence to a Hatch of Y_1 5%	Y_2 15%	Y_3 50%	Y_4 90%
	June				
1951	15	31	37	44	56
1950	10	39	44	54	66
1949	17	30	33	40	48
	July				
1948	8	19	23	28	42
	June				
1947	24	27	20	38	44
1946	27	20	21	27	35

Regression formula $\hat{Y}=\bar{y}+\frac{Sxy}{Sx^2}(X-\bar{x})$

$\hat{Y}_1=42.8-.69473X$ $\hat{Y}_3=58.3-.91182X$

$\hat{Y}_2=48.1-.77094X$ $\hat{Y}_4=67.6-.87602X$

Table 2.—Computation of formulae from emergence of 5 per cent of moths.

Year	X Emergence Date	Number Days from 5% of Moth Emergence to Hatch of Y_1 5%	Y_2 15%	Y_3 50%	Y_4 90%
	June				
1951	30	16	22	29	41
	July				
1950	6	13	18	28	40
1949	1	16	19	26	34
1948	14	13	17	22	36
1947	10	11	14	21	28
	June				
1946	30	17	18	24	32

Regression formula $\hat{Y}=\bar{y}+\frac{Sxy}{Sx^2}(X-\bar{x})$

$\hat{Y}_1=16.06-.33754X$ $\hat{Y}_3=26.90-.36450X$

$\hat{Y}_2=19.6-.30664X$ $\hat{Y}_4=36.17-.18607X$

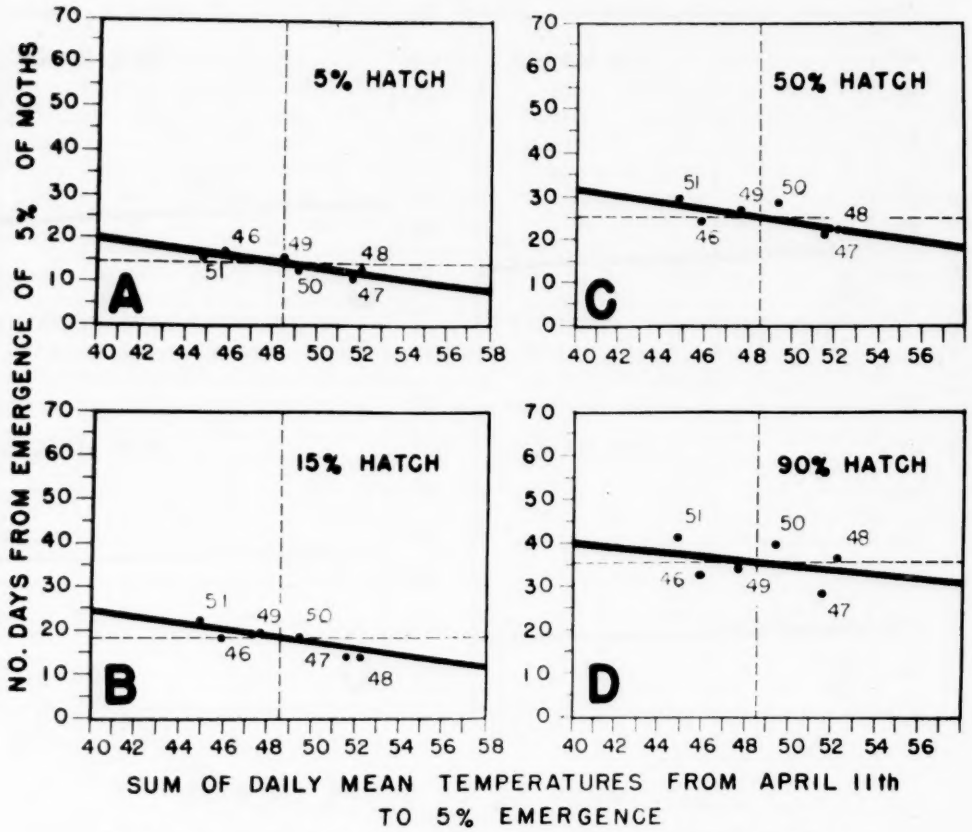

FIG. 3.—Summation of daily mean temperatures in relation to hatching levels of the European corn borer.

Table 3.—Forecasting egg hatch from sum of daily mean temperatures from April 11 to date of emergence of 5 per cent of corn borer moths.

Year	X Accumulated Temperature at Date of 5% Emergence	Days from 5% Moth Emergence to Hatch of Y_1 5%	Y_2 15%	Y_3 50%	Y_4 90%
1951	4483.5	16	22	29	41
1950	4916.5	13	18	28	40
1949	4763.5	16	19	26	34
1948	5201.0	13	17	22	36
1947	5151.5	11	14	21	28
1946	4589.0	17	18	24	32

Regression formula $\hat{Y} = \bar{y} + \frac{Sxy}{Sx^2}(X - \bar{x})$

$\hat{Y}_1 = 48.4 - .00703X$ $\hat{Y}_3 = 62.9 - .00782X$

$\hat{Y}_2 = 53.2 - .00726X$ $\hat{Y}_4 = 66.3 - .00644X$

DISCUSSION.—Figure 1 shows the regressions of the number of days from 0.05 per cent moth emergence upon the date of hatch of corn borer eggs. The regression in figure 1A is of the number of days from 0.05 per cent moth emergence upon the date of 5 per cent hatch.

Table 4.—Date of hatching in relation to the summation of the daily mean temperature from April 11 until the date of emergence of 5 per cent of the moths.

Hatching Levels (Percentage)	Mean 5% Emergence Date	Mean Summation of Temperature[2]	Mean No. Days After 5% Emergence to Hatching Levels	r
5%	July 5.2	4850.8	14.3	−.881[1]
15%	July 5.2	4850.8	18.0	−.815[1]
50%	July 5.2	4850.8	25.0	−.710
90%	July 5.2	4850.8	35.2	−.383

[1] When "r" exceeds .811 the correlation is considered significant (5%).

[2] Mean summation of daily mean temperatures from April 11 to date of 5% emergence.

Table 5.—Date of hatching in relation to the date of moth emergence, 1946–51.

HATCHING LEVELS (PERCENT)	MEAN .05% EMERGENCE DATE	DAYS TO HATCHING LEVELS	r	MEAN 5% EMERGENCE DATE	DAYS TO HATCHING LEVELS	r
5%	June 21.8	27.7	−.932*	July 5.2	14.3	−.849[1]
15%	June 21.8	31.3	−.895*	July 5.2	18.0	−.692
50%	June 21.8	38.5	−.901*	July 5.2	25.0	−.665
90%	June 21.8	48.5	−.797	July 5.2	35.2	−.223

[1] When "r" exceeds .811 the correlation is considered significant (5%).

In this particular case the actual data lie rather close to the regression line. In figure 1B the line conforms to 15 per cent hatch, in 1C to 50 per cent, and in 1D to 90 per cent hatch. As the percentage of hatch increases the error is likewise greater.

In figure 2 regression is of the days from the emergence of 5 per cent of the moths and upon the dates when the eggs hatched. Here also the 5 per cent level is more accurate than that for the higher levels of 15, 50, and 90 per cent.

The data used in figure 3 are the days from 5 per cent moth emergence and the sum of daily mean temperature expressed in hundreds. At the 5 per cent level the time of hatching is in no case more than 1 day in error. Levels of 15 per cent, 50, and 90 per cent were less accurate (figure 3, B, C, and D).

Without reference to the actual graphs

Table 6.—Evaluation of three methods for forecasting hatching levels of corn borer eggs.

ACTUAL DATE OF HATCHING	FORECASTED DATE OF HATCH FROM: Emergence of .05% of Moths	Emergence of 5% of Moths	Summation of Mean Temperatures[1]	MEAN OF A, B, C (DATES)	MEAN ERROR OF ESTIMATE (DAYS)
		5% Hatching Level			
1951 July 16	July 17.4	July 16.1	July 16.1	July 16.5	+ .5
1950 July 19	July 15.9	July 20.0	July 19.8	July 18.6	− .4
1949 July 17	July 18.0	July 17.0	July 15.9	July 17.0	0
1948 July 27	July 24.4	July 25.4	July 25.8	July 25.2	−1.8
1947 July 21	July 20.1	July 22.7	July 22.2	July 21.7	+ .7
1946 July 17	July 21.0	July 16.1	July 16.1	July 17.7	+ .7
		15% Hatching Level			
1951 July 22	July 21.5	July 19.6	July 20.6	July 20.6	−1.4
1950 July 24	July 20.4	July 23.8	July 23.5	July 22.6	−1.4
1949 July 20	July 22.0	July 20.3	July 19.6	July 20.6	+ .6
1948 July 31	July 26.8	July 29.3	July 29.4	July 28.5	−2.5
1947 July 24	July 23.6	July 26.5	July 25.8	July 25.3	+1.3
1946 July 18	July 24.3	July 19.6	July 19.9	July 21.3	+3.3
		50% Hatching Level			
1951 July 29	July 26.9	July 29.6	July 27.8	July 28.1	− .9
1950 Aug. 3	July 30.7	July 29.2	July 30.5	July 30.1	−3.9
1949 July 27	Aug. 27.5	July 29.7	July 26.6	July 27.9	+ .9
1948 Aug. 5	Aug. 4.8	Aug. .7	Aug. 5.2	Aug. 3.6	−1.4
1947 Aug. 1	Aug. 3.3	July 30.4	Aug. 2.6	Aug. 1.8	+ .8
1946 July 24	July 26.9	July 30.7	July 27.0	July 28.2	+4.2
		90% Hatching Level			
1951 Aug. 10	Aug. 8.5	Aug. 5.2	Aug. 6.4	Aug. 6.7	−3.3
1950 Aug. 15	Aug. 7.8	Aug. 10.1	Aug. 9.6	Aug. 9.2	−5.8
1949 Aug. 4	Aug. 8.7	Aug. 6.0	Aug. 5.6	Aug. 6.9	+2.9
1948 Aug. 19	Aug. 11.3	Aug. 16.6	Aug. 15.8	Aug. 14.6	−4.4
1947 Aug. 7	Aug. 9.6	Aug. 13.3	Aug. 12.1	Aug. 11.7	+4.7
1946 Aug. 1	Aug. 9.9	Aug. 5.2	Aug. 5.7	Aug. 6.9	+5.9

[1] Summation of daily mean temperature from April 11 to date of 5 per cent moth emergence.

the hatching dates may also be computed algebraically by using the linear regression equations. In this case the date of 0.05 per cent moth emergence is substituted in place of X in table 1, of 5 per cent emergence in place of X in table 2, and the sum of the daily mean temperatures from April 11 until the date of 5 per cent moth emergence in place of X in table 3. In each case the resulting Y is the estimated number of days that will elapse until the hatching level for which the formula was established. Correlation coefficients between the mean of 0.05 per cent emergence date and the mean number of days to hatching levels, and between the mean of 5 per cent emergence date and the mean number of *days to hatching* levels are listed in the r column of table 5. Correlation coefficients between the mean summation of temperature from April 11 to the date of 5 per cent moth emergence, and the mean number of days with the number of days to hatching are listed in table 4.

Statistical analysis indicates that the forecasting of the 5 per cent egg hatch is significantly reliable (at odds of 19:1) for all three methods; that the forecasting of the 15 per cent hatch is significantly reliable for the first and third methods; and that the forecasting of the 50 per cent hatch is significantly reliable for the first method.

The three methods used for forecasting the levels of hatching of the European corn borer are evaluated in table 6. The mean error of estimate in days is shown in the right hand column of table 6. However, when all three methods are combined and their mean is used, the maximum error between the forecast hatching date and actual occurrence is 1.8 days for the date of 5 per cent hatching level, 3.3 days for the 15 per cent level, 4.2 days for the 50 per cent level, and 5.9 days for the 90 per cent level.

For five of the six years the mean of the three methods forecasts within one day the actual date of 5 per cent hatching level. For four of the six years the mean of the three methods forecasts within 1.4 days the actual date of both the 15 per cent and the 50 per cent hatch. For four years using the same data mean forecasts were within 4.7 days the actual date of the 90 per cent hatching level.

During the 6-year period, from the date of emergence of .05 per cent of the moths there is a mean of 27.7 days until the date of 5 per cent egg hatch, of 31.3 days until 15 per cent hatch, of 38.5 days until 50 per cent hatch, and of 48.5 days until 90 per cent hatch. From the date of emergence of 5 per cent of the moths there is a mean of 14.3 days until the date of 5 per cent egg hatch, of 18.0 days until 15 per cent hatch, of 25.0 days until 50 per cent hatch, and 35.2 days until 90 per cent hatch. This provides ample time for the forecaster to notify the corn growers when to apply insecticides for probably more economical control. It seems probable that additional data secured over an extended period of time will produce linear regression formulae, which would add to the accuracy of forecasting hatching levels.

SUMMARY.—Investigations in methods of timing applications of European corn borer insecticides have been in progress at St. Albans and Newport, Maine, since 1946. Relation between hatching of the borers and the effectiveness of insecticidal applications led to further study and a consideration of the value of regression lines in forecasting the dates when a given hatching level of the European corn borer could be expected.

Three methods are used in forecasting the dates of hatching levels, (1) the relationship between the emergence of .05 per cent of the moths and the hatching dates; (2) the relationship between 5 per cent of the moths and the hatching dates; and (3) the relationship between the sum of the daily mean temperature from April 11 until the date of 5 per cent emergence and the hatching dates.

Figures including regression lines comprise illustrations of each of the three methods employed for studying the data. They include data for comparing actual dates of 5, 15, 50, and 90 per cent levels of hatching with dates as forecasted for each of the four levels for a 6-year period. Accuracy is improved by using the mean of the three methods described. The mean error of estimate is then 1.8 days for the 5 per cent hatching level, 3.3 days for the 15 per cent level, 4.2 days for the 50 per cent level, and 5.9 days for the 90 per cent hatching level. Six tables are included for reference.

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Further Investigations of Insecticides for Control of Insects Attacking Ornamental Trees and Shrubs[1]

T. W. KERR, JR., *University of Rhode Island, Kingston*

In previous publications the writer (Kerr 1950, 1951) has reported on the comparative insecticidal effectiveness and timing of application of several old and new insecticides for control of 13 species of insects attacking ornamental trees and shrubs. This report is a continuation of those investigations. It concerns field experiments undertaken in 1951 involving the balsam twig aphid, *Mindarus abietinus* Koch, the Cooley spruce gall aphid, *Chermes cooleyi* Gill., the willow sawfly, *Nematus ventralis* Say, the eastern tent caterpillar, *Malacosoma americanum* (F.), the euonymus scale, *Unaspis euonymi* (Comst.), and *Leucaspis japonica* Ckll., a species of scale insect having no accepted common name.

MATERIALS.—The details relative to the materials and concentrations used in each experiment are given in tables 1 to 6. All of the chlorinated hydrocarbon insecticides were wettable powders and included 50 per cent DDT, 50 per cent methoxychlor, 25 per cent lindane, and 10 per cent of a new material (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8a-octahydro-1,4,5,8,-endo-endo-dimethanonaphthalene).[2] Nicotine sulfate was employed as the conventional 40 per cent solution. Acid lead arsenate was used in two experiments. In one, it was combined with hydrated lime, while in the other it was used in combination with a sticking agent composed of protein materials and a clay. An additional wetting agent[3] was used with the chlorinated hydrocarbon insecticides and with nicotine sulfate as indicated in several of the experiments. All materials were applied as sprays using a conventional power-operated, hydraulic sprayer and spray gun.

Table 1.—Control of the balsam twig aphid with various insecticides. Wakefield, R. I., May, 1951.

MATERIAL[1]	INSECTICIDE POUNDS IN 100 GAL.	APHIDS PER CM. OF TWIG	PER CENT CONTROL
Nicotine sulfate	1 pt.	0.21	98.8
Lindane 25% W	0.5 lb.	0.21	98.8
	1 lb.	0.04	99.7
Check		16.76	

[1] The wetting agent at the rate of 8 ounces in 100 gallons of water was included with each insecticide.

BALSAM TWIG APHID.—Much of the balsam fir grown in Rhode Island is attacked by this insect each year. In some areas injury has been severe enough to devitalize the trees seriously. The tender, new growth is attacked almost as soon as it appears. Severely injured twigs become stunted, distorted and eventually die. Three balsam fir and one Arizona fir, averaging 12 feet in height, were used in the tests. On May 15, when the insecticides were applied, the trees were infested with an average of 12.9

[1] Contribution No. 780 from the Rhode Island Agricultural Experiment Station, Kingston, R. I.
[2] Referred to in this paper as "TM-1" (Test Material #1).
[3] Triton B-1956, a phthalic glyceryl alkyd resin.

Table 2.—Control of the Cooley spruce gall aphid with various insecticides. Wakefield, R. I., May, 1951.

Material[1]	Pounds in 100 Gal. Water	Aphids per cm. of Twig	Per Cent Control
		No.	
Nicotine sulfate 40%	1 pt.	0.00	100.0
Lindane 25% W	0.5 lb.	1.28	91.3
	1 lb.	0.23	98.4
DDT 50% W	1 lb.	14.26	3.6
	2 lb.	3.38	77.1
Check		14.78	

[1] A wetting agent at the rate of 6 ounches in 100 gallons of water was included with each insecticide.

aphids per centimeter of twig. At that time, the length of new growth averaged 1.7 centimeters per twig. On May 21, data on control were obtained by counting the number of aphids on 100 random twigs from the tree included in each treatment. Results given in table 1 show both nicotine sulfate and lindane effective for control of the balsam twig aphid. There was little difference in the degree of control obtained with one-half or with one pound of wettable 25 per cent lindane.

COOLEY SPRUCE GALL APHID.—Each year this insect has been a serious pest of Douglas fir used for ornamental purposes. The experiment was conducted on trees averaging 6 feet in height and heavily infested with aphids. Four replicated trees were used for each treatment. When the insecticides were applied on May 22, almost all of the eggs produced by the adult sistens had hatched. Data on control were obtained on May 28 by counting the number of live aphids on the new growth of 25 random twigs from each tree in all treatments. Results given in table 2 show that nicotine sulfate, the standard insecticide (Annand 1928), and lindane were effective in controlling the insect. DDT was relatively ineffective.

WILLOW SAWFLY.—Fortunately this insect is only an occasional pest, for when numerous it is a vigorous defoliator of isolated plantings of willow. In 1951 it was found to be especially numerous on willow in several nursery plantings in Middletown. Using a block of approximately 650 trees averaging 4 feet in height for each treatment, the materials listed in table 3 were applied on June 26. At that time, 73 per cent of the trees showed an average of 82.5 larvae per infested tree. One hundred trees in each treatment were examined for live larvae at the end of 3 days and again at the expiration of 27 days. The data show that DDT, methoxychlor and lead arsenate were effective for control of the insect. At the end of 27 days all three materials, except DDT at the greater dilution, had sufficient residual activity to prevent reinfestation.

Table 3.—Control of the willow sawfly with various insecticides. Middletown, R. I., June and July, 1951.

Material[1]	Pounds in 100 Gal. Water	Per Cent Sawfly Control in	
		3 Days	27 Days
DDT 50% W	0.5	100.0	84.3
	1	100.0	99.4
	2	100.0	99.9
Methoxychlor 50% W	1	100.0	99.3
	2	100.0	99.9
Lead arsenate sticker	3 1	100.0	99.8

[1] The wetting agent at the rate of 4 ounches in 100 gallons of water was included with each insecticide except lead arsenate.

EASTERN TENT CATERPILLAR.—This insect has become increasingly abundant during the past two seasons. Host plants included in the experiment were wild cherry and apple. Each of the treatments and the unsprayed check consisted of 15 trees containing nests with a total of approximately 1900 larvae. On May 7 and 8 the materials listed in table 4 were applied to the nests and surrounding

Table 4.—Control of the eastern tent caterpillar with various insecticides. South Kingstown-Richmond, R. I., May, 1951.

Material[1]	Pounds in 100 Gal. Water	Per Cent Control in	
		5 Days	14 Days
DDT 50% W	0.5	99.7	100.0
	1	100.0	100.0
	2	100.0	100.0
Methoxychlor 50% W	0.5	98.9	100.0
	1	100.0	100.0
	2	100.0	100.0
Lead arsenate lime	3 6	74.0	100.0

[1] A wetting agent at the rate of 4 ounces in 100 gallons of water was included with each insecticide except lead arsenate.

foliage. At that time, the average length of some larvae was 8 millimeters, while others averaged 14 millimeters. No attempt was made to spray all of the developing leaves. Data on control were obtained 5 and 14 days after the sprays were applied. Both DDT and methoxychlor acted much faster than did lead arsenate, the standard material (Wadley 1947). Most of the larvae on plants sprayed with DDT and methoxychlor were dead within 48 hours, while those sprayed with lead arsenate succumbed at a much slower rate. Stearns, *et al.* (1948) have shown that 2 pounds of wettable 50 per cent DDT was 100 per cent effective for control of the insect. The data presented here indicate that one-fourth that dosage of either DDT or methoxychlor was sufficient for control.

EUONYMUS SCALE.—This insect is the most widespread and serious pest of euonymus in Rhode Island. It is especially destructive to the several varieties of winter-creeper euonymus. Two generations of the insect occur each season. Crawlers of the first generation were found on May 30. Tests were conducted on baby wintercreeper, *Euonymus fortunei minima*, a climbing variety, the vegetative parts of which tend to cling to the object on which it climbs. Sixty square feet of plant area on a wall was provided for each of the treatments. On June 6, when the first application was made of the materials listed in table 5, there was an average of 187.6 crawlers per leaf on 50 random leaves. As indicated, some of the plots received a second spray application 12 days later. During the period of July 20 to 26, data on control were obtained by counting the number of live scales on 50 random leaves in each treatment. At that time, there was an average of 247.3 male and 67.6 female scales per leaf in the check treatment. Results given in table 5 show that DDT was the most effective material for controlling the insect. Neither the amount of DDT used nor the number of applications influenced the degree of control of the female scale. On the other hand, DDT was slightly less effective against the male scale, particularly when 1 pound of 50 per cent DDT was applied once. Nicotine sulfate was somewhat less effective than DDT. Lindane and TM-1 were both ineffective. The large scale population found in these two treatments

Table 5.—Control of first generation nymphs of the euonymus scale. South Kingston, Rhode Island, June–July, 1951.

Material[1]	Amount in 100 Gal. Water	Applications	Control	
			Male	Female
		No.	%	%
DDT 50%W	1 lb.	1	96.0	99.6
	1 lb.	2	99.4	100.0
	2 lb.	1	99.9	99.8
	2 lb.	2	99.9	99.9
Nicotine sulfate 40%	1 pt.	1	85.0	79.7
	1 pt.	2	94.3	96.3
Lindane 25%W	1 lb.	2	12.1[2]	12.4[2]
TM-1 10%W	1 lb.	2	17.1[2]	58.3[2]

[1] Wetting agent at the rate of 4 ounces in 100 gallons of water was applied with each insecticide.
[2] Denotes increased scale population rather than control.

may be attributed to the adverse influence of the materials on various coccinellid predators that actively fed on the immature scales during the course of the experiment.

Leucaspis japonica.—This scale has been found in one small coastal area of Rhode Island. Plants attacked are sycamore maple, privet, winged euonymus, dogwood, hawthorn and mountain ash. Severely infested plants are not only devitalized but may succumb as a result. The insect is found primarily on the trunk and larger branches of the host. Except when the infestation is heavy, the new growth or leaves are not attacked.

In 1951, crawlers were seen first on July 5. On July 9, eggs under 27 per cent of the females had hatched. This was increased to 40 per cent on July 18, 61 per cent on July 30, and 76 per cent on August 9. In October and early November, a few newly-hatched crawlers and egg-laying females were found among the immature male and female scales, particularly on untreated plants.

An experiment was conducted on common privet, *Ligustrum vulgare*, averaging 7 feet in height and moderately infested with scale. Each treatment was applied to 4 isolated plants on July 9 and July 18 at the rates indicated in table 6. On July 30 and August 9, two of the plants in each treatment received a third and a fourth application of spray. Data on control were obtained during the period of November 8 to 20 when 500 square centimeters of bark from each plant in all treatments was examined for live scale. The results presented in table 6 show that nicotine sulfate was effective for controlling the insect while DDT was ineffective. A quart of nicotine sulfate was more ef-

Table 6.—Control of *Leucaspis japonica* Ckll. with various insecticides. Westerly, R. I., July–November, 1951.

Material[1]	Amount in 100 gal. Water	Applications	Scales per cm.² of Bark	Control
		No.	No.	%
Nicotine sulfate 40%	1 pt.	2	5.54	48.6
		4	1.15	89.3
	2 pt.	2	0.53	95.1
		4	0.41	96.2
DDT 50%W	1 lb.	2	10.12	6.1
		4	10.72	0.5
	2 lb.	2	7.60	29.5
		4	7.21	33.0
Check			10.78	

[1] Wetting agent at the rate of 4 ounces in 100 gallons of water was included with each insecticide.

fective than a pint, but there was no difference in the degree of control obtained with 2 and 4 applications of the greater concentration.

SUMMARY.—During 1951 the comparative insecticidal effectiveness of several wettable chlorinated hydrocarbon materials, 40 per cent nicotine sulfate and acid lead arsenate, and the timing of insecticide applications, was investigated in field tests involving six insects attacking ornamental trees and shrubs.

Both nicotine sulfate and 25 per cent lindane were effective for control of the balsam twig aphid. One application of 1 pint of the former insecticide or 8 or 16 ounces of the latter in 100 gallons of water resulted in more than 98 per cent control of the insect. Application was made in mid-May when the length of new growth averaged 1.7 centimeters per twig.

A single application of 1 pint of nicotine sulfate in 100 gallons of water was 100 per cent effective in controlling the Cooley spruce gall aphid on Douglas fir. Twenty-five per cent lindane at the rates of 16 ounces and 8 ounces was 98.4 and 91.3 per cent effective, respectively. Fifty per cent DDT was relatively ineffective. Application was made shortly after mid-May when almost all of the eggs produced by the adult sistens had hatched.

Fifty per cent DDT, 50 per cent methoxychlor and lead arsenate were effective in single applications for control of the willow sawfly. One and 2 pounds of the chlorinated hydrocarbons and 4 pounds of the arsenical with 1 pound of sticker in 100 gallons of water were 100 per cent effective against the larval stage. All treatments, except DDT at 8 ounces in 100 gallons of water, had sufficient residual activity to prevent reinfestation for 27 days.

Fifty per cent DDT, 50 per cent methoxychlor and lead arsenate were 100 per cent effective in single applications for control of the larval stage of the eastern tent caterpillar. As little as 8 ounces of the chlorinated hydrocarbon materials in 100 gallons of water was as effective as 3 pounds of the arsenical with 6 pounds of hydrated lime. In addition, the insecticidal action of both DDT and methoxychlor was more rapid than that of lead arsenate.

Both 50 per cent DDT and nicotine sulfate were effective for control of newly-hatched crawlers of the euonymus scale, with the former insecticide slightly superior to the latter. One application of one pound of 50 per cent DDT in 100 gallons of water resulted in 99.6 control of the female scale, while two applications of nicotine sulfate produced 96.3 per cent control. Lindane and TM-1 were ineffective for control of the insect.

Nicotine sulfate was effective and DDT ineffective for control of *Leucaspis japonica* Ckll. on common privet. Two applications containing 1 quart of nicotine sulfate in 100 gallons of water proved more effective than four applications containing 1 pint of the insecticide. There was no difference between the control obtained with two and that with four applications of the greater concentration. Insecticice applications which began on July 9 and ended August 9 and were spaced 9, 12 and 10 days apart, respectively.

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Persistence of Insecticide Residues on Forage Crops[1]

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Until recently the insect and other arthropod pests of forage crops were very difficult, it not impossible, to control. The use of hopperdozzers, tanglefoot, brush and wire drags, poultry and hogs, timely clipping, clean culture and rotations were all commonly suggested in the early literature although they gave only a fair degree of success on a comparatively few insects of forage crops. Such inorganic insecticides as calcium arsenate, lead arsenate, cryolite, zinc arsenate and sulfur were also used with some success but the results were often poor at best. However, with the advent of DDT and some of the other synthetic organic insecticides, the control of many, if not most, of the pests of forage crops was made possible. Several workers have shown that significant increases in hay yields and legume seed yields were possible with the use of small amounts of organic insecticides, but data have been lacking on the exact magnitude of residue of such applications at harvest. While it was thought that very low residues of insecticides of less than 2 ppm of many of the organic insecticides on forage crops would not affect the health of dairy cattle or produce detectable residues in their milk, the lack of exact data on this point has prevented the recommendation of the organic materials for forage application. Therefore in conjunction with tests of feeding to dairy cattle forage treated with low levels of insecticide residues, experimental work was initiated in 1949 to determine the exact magnitude of organic insecticide residues on forage from various weekly schedules of applications of insecticides under field conditions in New York.

METHODS AND MATERIALS.—The insecticides used in the investigations in 1950 included 1 per cent impregnated proprietary dust of technical DDT, purified DDT, parathion, aldrin, lindane, benzene hexachloride and a 5 per cent ribbon mill mixed dust of technical DDT.

The insecticides were applied on alfalfa of the variety Ontario Varigated in plots which were 10 feet by 20 feet in size, replicated 3 times and randomized in blocks. All of the dusts were weighed out for each plot, mixed with additional inert diluent and applied with a hand fertilizer spreader at a rate of 2 pounds of actual toxicant per acre. The applications were made in a split weekly schedule so that at the end of 3 weeks, 3 plots had received one application of each toxicant, 3 had received two applications, 3 had received 3 applications and three plots remained untreated as checks.

The hand fertilizer spreader rather than a hand duster was used for several reasons. It is highly adaptable to small plots, prevents most of the drift, and gives an even distribution of the materials.

Samples of the standing hay were taken for chemical analysis of the residues at the time of each application and at weekly intervals thereafter. These samples consisted of 3 square feet of alfalfa per plot chosen at random and were taken with the aid of a metal frame, enclosing 1 square foot. A sharp knife was used for cutting all of the hay enclosed by the frame at cutter bar height. The samples of hay were weighed green and stripped immediately after the sampling in order to prevent any residue loss. The residue determinations were calculated from these weights. Dry weight determinations were not made in this particular experiment. However, in other experiments the green-dry weight ratios were determined. Those figures indicated that the dry weight amounted to about 35 to 40 per cent of the green weights at harvest. If the calculations were made on a dry weight basis the residues would then be approximately 2.5 to 3 times greater than residues calculated on a green weight basis. Samples taken at intervals previous to harvest have a higher percentage of moisture and consequently will have a lower percentage of dry matter. This follows a definite trend and as the crop grows the per cent of dry matter increases proportionately. The data clearly indicate the importance of identifying the method of residue determinations when residue data are reported.

The parathion and DDT residues were stripped with commercial benzene; lindane and benzene hexachloride residues

[1] Funds provided by the Geigy Co. Inc. New York, N. Y.

Table 1.—Results of the chemical analysis of hay samples taken from plots of alfalfa that had received one, two or three applications of five organic insecticides. Minetto (Oswego County), New York. 1950.

Insecticide	Number Appl.	P/A Act. Txc.	Residue in ppm, Days After Last Application					
			0	7	14	21	30	42
Parathion	1	2	12.3	0.5	0.3	0.1	—	0.00
	2	4	4.2	2.0	0.2	0.4	0.00	—
	3	6	12.6	0.6	.31	.06	0.00	—
Aldrin	1	2	3.2	0.2	−.52	.09	—	−.24
	2	4	3.18	−.29	−.19	.19	0.00	—
	3	6	13.17	−.19	.40	.38	.18	—
Lindane	1	2	11.4	.67	—	.2	—	.1
	2	4	13.4	4.5	.7	.19	.7	—
	3	6	13.0	1.9	.83	.18	1.15	—
Benzene hexachloride	1	2	59.6	2.3	2.0	.22	—	.62
	2	4	10.2	6.4	1.1	.30	1.6	—
	3	6	38.0	7.2	5.4	1.8	3.6	—
DDT (5%)	1	2	102.6	9.0	5.6	0.9	—	0.4
	2	4	47.8	21.9	16.2	9.2	3.0	—
	3	6	179.8	36.1	7.7	5.5	1.4	—
DDT (Tech)	1	2	104.6	7.9	5.0	1.4	—	0.6
	2	4	97.7	24.2	7.8	2.0	2.2	—
	3	6	175.7	41.6	30.7	12.7	4.0	—
DDT (purified)	1	2	28.9	4.5	1.8	0.00	—	0.00
	2	4	25.1	6.0	6.9	1.9	1.0	—
	3	6	16.6	5.6	2.6	1.6	0.6	—

with ethyl ether and aldrin residues with a petroleum ether.

The samples of hay were stripped in glass jars which were rotated end over end for 15 minutes. At the end of this time the strippings were poured into glass bottles which were sealed with corks wrapped in tinfoil. All of the bottled samples except parathion were stored in a cooler until they were analyzed. The parathion samples, which are less stable, were analyzed immediately.

The DDT samples were analyzed by the colorimetric method of Schecter, *et al.* (1945). The parathion samples were analyzed by the Averell-Norris method (1948). Aldrin was analyzed by the Danish-Lidov method (1950), while lindane and benzene hexachloride were analyzed by the method of Tufts *et al.* (1950).

Before any DDT analysis could be made, the strippings had to be cleared of a substance that interfered in the colorimetric reading. This interfering substance was removed by filtering the aliquot to be analyzed through a 2.5 to 3 inch column of aluminum oxide as described by Norton & Schmalzreidt (1950).

Results.—The results of the chemical analysis are recorded in table 1. This table contains the residues in parts per million based on the green weights.

All of the insecticides showed a loss greater than 98 per cent of the original deposit in 21 days where one application was made. Those plots that received additional applications showed a loss slightly less than the residue loss from a single application. As the number of applications were increased the rate of residue loss was decreased. The comparison of the relative residue loss for each insecticide is illustrated in figure 1. These curves were obtained by plotting the per cent of the initial deposit remaining after each sampling date and drawing a best fitting line between the points.

The insecticides which disappear most rapidly (parathion and aldrin) have a very narrow difference between rates of loss of residues from one, two or three applications of the insecticide and the curves for the two materials are very similar.

In general it may be said that parathion residues disappear more rapidly than do those of the other insecticides tested.

Table 2.—The hay yields in tons per acre based on green weight and calculated from weight of samples taken for residue analysis. Minetto, N. Y. 1950.

Insecticide	Number of Applications	P/A Act. Txc.	Av. Yields in Tons per Acre (green wt.) on Following Sampling Dates					Increase Over Check at Harvest (Tons)	Per Cent Increase Over Check
			5-20	5-28	6-2	6-10	7-1		
Parathion	1	2	4.17	6.64	6.81	9.11	16.01	.16	1.0
	2	4	—	8.48	6.24	9.95	18.14	2.29	14.5
	3	6	—	—	6.65	11.058	12.83		
Aldrin	1	2	4.45	6.03	7.29	9.05	21.10	5.25	33.1
	2	4	—	6.66	6.41	8.52	13.70	—	—
	3	6	—	—	7.26	9.40	12.95	—	—
Lindane	1	2	4.32	8.49	—	9.65	16.87	1.02	6.4
	2	4	—	7.71	6.92	9.34	16.30	0.45	2.8
	3	6	—	—	6.70	8.97	12.13	—	—
Benzene hexachloride	1	2	4.08	5.02	6.66	8.04	13.09	—	—
	2	4	—	8.71	6.64	9.14	12.97	—	—
	3	6	—	—	6.63	10.19	15.14	1.29	9.3
DDT mechanical mixture	1	2	4.12	6.79	6.93	7.39	7.23	—	—
	2	4	—	9.26	8.84	11.29	18.55	2.70	17.0
	3	6	—	—	7.30	13.66	15.51	1.66	12.0
DDT Technical	1	2	3.49	5.76	6.90	8.44	19.01	3.16	19.9
	2	4	—	5.38	5.71	8.72	17.36	1.51	9.5
	3	6	—	—	6.74	7.28	14.42	0.57	4.1
DDT Purified	1	2	3.72	5.39	6.93	7.53	14.84	—	—
	2	4	—	6.89	6.59	9.22	14.89	—	—
	3	6	—	—	5.96	7.72	17.64	3.79	27.4
Check 1 (for 1 appl.)	—	—	5.05	6.48	7.20	9.93	15.85	—	—
Check 2 (for 2 appl.)	—	—	—	6.49	8.90	9.85	15.85	—	—
Check 3 (for 3 appl.)	—	—	—	—	8.22	11.46	13.84	—	—

However, the loss of aldrin closely parallels that of parathion but the residues of aldrin are more persistent and require a longer weathering period before their residues reach insignificant levels. Aldrin, while more persistent than parathion, does not approach lindane in persistency of residue. The residues of lindane, which are more persistent than aldrin residues, are lost more rapidly than the residues of benzene hexachloride. Lindane reaches its maximum loss in about 40 days while benzene hexachloride residues require 45 to 50 days to reach insignificant levels. Benzene hexachloride residues are lost only slightly faster than residues of DDT.

DISCUSSION.—The two main factors in causing disappearance of insecticide residues on crops are weathering and growth. Weathering reduces the deposits by physical and chemical actions. Growth affects the deposits by scattering the insecticide over a greater area and mass although it is not strictly a method of residue loss. Therefore in the chemical analysis, growth produces an apparent residue loss on the weight or area basis even when chemical or physical forces have destroyed none of the original deposit.

In order to understand better the losses of residue from alfalfa in the field, a record was kept of the yields of hay at the various residue sampling dates. The change in yield from sampling date to sampling date is indicative of the growth and is directly proportional to residue loss if all other contributing factors are eliminated, see table 2. Although the figures for yields in table 2 are based on samples much too small to be an accurate measure of the

Table 3.—Accumulative precipitation at various intervals from the last date of treatment for each weekly schedule until harvest. Minetto (Oswego Co.) New York. 1950.

Number of Treatments	Amount of Precipitation to Which the Residues Had Been Subjected during the Week Preceding the Sampling Dates						
	5–20	5–28	6–2	6–10	6–17	6–24	7–1
1	T[1]	0.41	1.61	2.14	2.18	3.79	3.81
2	T	T	1.20	1.73	1.75	3.36	3.40
3	T	T	T	0.53	0.55	2.16	2.20

[1] T indicates date of treatments.

actual yields it is quite obvious that the mass of hay at harvest is 3 to 5 times that of the hay at the date of the first application of insecticide. Therefore if all weather factors are disregarded, residue loss from growth alone would be from 60 to 80 per cent of the original deposit in a period of 4 to 6 weeks. This may be noted in the yields of hay for the various treatments and treatment schedules. The variations shown in the yield table cannot be considered significant because of the small sample size, the poor validity of green weights and the lack of an insect infestation in the experiment.

Precipitation was recorded daily and calculated as accumulated rainfall between sampling dates for the residues. It is obvious from table 3 that each application of insecticide was subjected to periodic and heavy precipitation. Where only one treatment was applied almost 4 inches of rain fell on the residues in the 7 weeks prior to harvest while almost 2.25 inches of rain fell on the last treatment alone in the 4 weeks prior to harvest for those treatments which received 3 applications. There is little reason to doubt that the rapid growth of alfalfa plus heavy precipitation contribute greatly to the rapid loss of residues in New York.

In examining the persistency of insecticide residues when only one application was made, it was found that parathion showed nearly a 100 per cent loss in 21 days and aldrin showed a similar loss in 28 days. These data indicate that residues from these two insecticides would be at a minimum or near zero under New York conditions when forage crops are harvested, as most control applications are made 5 to 7 weeks before harvest. When two applications of the insecticide were made, it required approximately an additional week to reduce the residues to insignificant amounts. Two applications of parathion required about 30 days for complete residue loss while adrin required about 36 days. When three applications were made the interval for substantially complete residue elimination time was increased still another week.

Table 4.—A comparison of the vapor pressure of five organic insecticides with the days required to reach insignificant levels and the average residues remaining after 14 days of weathering.

Insecticide	Vapor Pressure Rating[1]	Days Required to Reach Insignificant Levels	Residue Remaining After 14 Days. (ppm)
DDT	1×	40	6.8
Benzene hexachloride	6×[2]	37	2.8
Lindane	63×	32	.64
Aldrin	—	28	.37
Parathion	100×	21	.27

[1] Approximate vapor pressure ratings based on DDT equal 1.5×10^{-7} as 1.
[2] Estimated.

Although lindane residues were lost at a moderate rate it required about 32 days to eliminate the residues almost completely on alfalfa after one application had been made. Where two applications were made the time interval required for almost complete residue elimination was increased. After two applications of lindane had been made at weekly intervals it required about 45 days to reach insignificant levels. When three applications were made the interval necessary for apparently complete residue loss was not proportionally greater, requiring about 50 days.

Benzene hexachloride residues showed a fairly slow rate of loss. When one application was made it required about 37 days to eliminate the residues on alfalfa. When an additional application of benzene hexachloride was made a week later the residue persistence was increased, as might be expected. In this case it required about 48 days for the residues to reach an insignificant level. Where 3 applications were made at weekly intervals the time required for elimination of the residues was about 55 days. In general it seems to require approximately one and one-half additional weeks to reduce the residues of lindane and benzene hexachloride to negligible amounts when three applications are made at weekly intervals.

DDT residues are known to be quite persistent on various plants and forage crops are no exception. One application of DDT required about 40 days to give losses down to insignificant levels, which was somewhat longer than with the other materials tested. With additional applications of DDT the interval of time necessary for almost complete residue elimination was extended to about 52 days. However, when three applications were made at weekly intervals the time required for the residue to reach negligible amounts was about 60 days. Thus, it required about three additional weeks for DDT residues to become insignificant when three applications were made at weekly intervals.

Since it is obvious that the individual insecticides did not respond equally to the same growth and weathering factors and their losses could not be explained by either of these two methods, their respective vapor pressures were examined in hopes of explaining this difference. Recorded in table 4 are the vapor pressure ratings along with the days required to reach negligible levels and the average residues remaining 14 days after application of the dusts. From the data in this table it seems quite likely that the difference in the rate of loss of each insecticide may be partially explained from the respective vapor pressures of each insecticide. The volatility of parathion would theoretically place it at the top in rate of residue loss while DDT, which is rather persistent, would be at the bottom. In examining the data in table 4, especially the column headed "days required to reach insignificant levels" it is seen that DDT residues required the longest period for disappearance while parathion required the shortest interval as would be expected when their respective vapor pressures are examined. The other insecticides tested for which vapor pressures were known fall into line as expected in comparison with parathion and DDT. From examination of these data it appears that the volatility of each insecticide may play an important part in eventually eliminating the residues of the insecticides and that the differences ob-

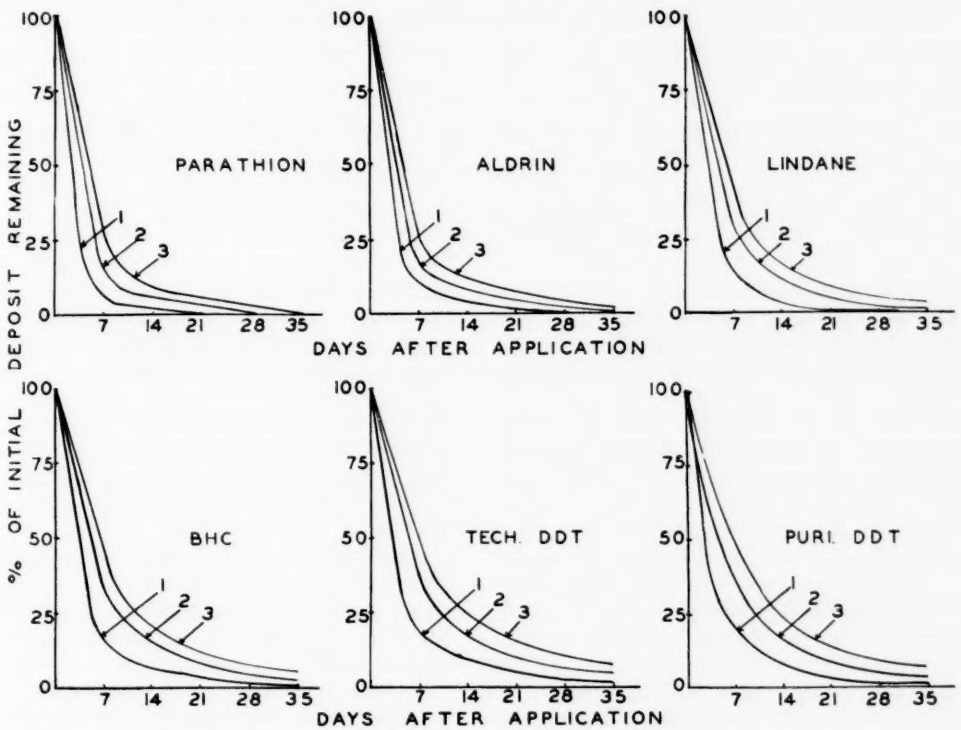

FIG. 1.—The residue loss of five organic insecticides when one, two, and three applications are made weekly to alfalfa. N. Y. 1950.

tained between different insecticides may also be partially accounted for by their vapor pressures.

SUMMARY.—In general, it can be said that regardless of the actual amount of insecticide applied to forage crops there is a very rapid loss of residue in 3 weeks. Then the residues taper off to a very low level where loss is much less rapid. Under New York conditions negligible levels of residue were found to exist after 30 days even when 6 pounds of actual toxicant of parathion, aldrin, lindane, benzene hexachloride, technical DDT and purified DDT were applied per acre. In most cases, except for DDT, these residues were less than 2 parts per million regardless of whether one, two or three applications were made. Residues of parathion and aldrin were lost most quickly, followed by lindane, benzene hexachloride and DDT in that order. Residues of technical DDT appeared to persist longer than those of purified or aerosol grade DDT but other experiments indicated that this longer persistence was not consistent.

Rapid growth of the alfalfa and heavy precipitation during the growing season are important factors in residue loss in New York. However, the contribution made by the volatility of the insecticide cannot be overlooked in the final analysis of the residue disappearance.

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Lindane as an Insecticide to Control Tobacco Moth and Cigarette Beetle

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In 1950 studies were made to determine the usefulness of lindane in oil as a contact insecticide against the tobacco moth, *Ephestia elutella* (Hbn.), and the cigarette beetle, *Lasioderma serricorne* (F.). The oil used in all tests was a light, volatile hydrocarbon having the following specifications: Maximum specific gravity at 60° F. 0.797, flash point 175° F., colorless, and with no kerosene odor. The results of these studies are reported in this paper.

SPACE SPRAYS.—*Laboratory Tests.*—A series of laboratory tests with lindane-oil space sprays were conducted in a modified Peet-Grady chamber of 20 cubic feet capacity. Each test was replicated six times. The test insects were freshly matured adults reared under controlled conditions. Prior to each test the plate-glass chamber was carefully cleaned, and the floor was covered with fresh blotting paper. Twenty-five moths and 25 beetles were liberated in the chamber, and the spray was applied through ports in the ends of the chamber. All the sprays were applied at a dosage of 100 ml. per 1000 cubic feet, and the concentrations of lindane varied from 0.125 to 4 per cent. The spray was atomized at a uniform pressure of 30 pounds per square inch. The test insects were exposed to the spray for 15 minutes. Ports in the chamber were then opened, a suction fan was started, and the chamber was air-washed for another 15 minutes. At the end of 30 minutes from the start of the test the chamber was opened and the insects were removed to wire-gauze cages for observa-

tion. Mortality of the tobacco moth was recorded 3 days after, and of the cigarette beetle 5 days after exposure to the spray. Previous work had indicated that there was little or no recovery of test insects after these periods, and with longer periods the mortality of check insects increased rapidly.

A spray containing 0.125 per cent of lindane killed 98 per cent of the tobacco moths. All sprays containing 0.25 per cent or more of lindane killed all the tobacco moths. The toxicity of lindane to the tobacco moth was approximately comparable to the known toxicity of the same strength of pyrethrum.

Against the cigarette beetle a spray containing 0.125 per cent of lindane gave 32 per cent mortality. Sprays containing 0.5 1, 2, 3, and 4 per cent of lindane gave 43, 75, 84, 95 and 96 per cent mortality, respectively. On the basis of these tests, a spray containing 2.5 to 3 per cent of lindane would be approximately as effective against the cigarette beetle as a similar spray containing 1 per cent of pyrethrins.

Warehouse Test.—Two large adjoining, open-type warehouses of flue-cured tobacco in hogsheads were sprayed once early in October. Both warehouses were heavily infested with the cigarette beetle. One warehouse was sprayed with pyrethrum-oil containing 0.89 per cent of pyrethrins (by weight), and the other with lindane-oil containing 2.85 per cent of lindane. The rate of application was 100 ml. (3 fluid ounces) per 1000 cubic feet of air space. The spray was applied with a mobile power sprayer designed especially for use in tobacco warehouses. At the time of application the air temperature was about 75° F., and there was a gentle breeze of approximately 3 to 4 miles per hour.

In each warehouse eight wire-gauze cages—four containing 25 tobacco moths each and four containing 25 beetles each were placed at random locations, ranging from floor level to 11 feet above the floor, and from 8 to 60 feet from the center aisle. Some cages were under hogsheads, some between hogsheads, and some on top of the hogsheads.

All the caged tobacco moths were killed in both warehouses; only 55 per cent of the cigarette beetles were killed with lindane and 60 per cent with pyrethrum. As the cages afforded some protection, the mortality of the cigarette beetles outside the cages was probably 80 and 85 per cent, respectively.

The effectiveness of the two sprays was further confirmed by the weekly catches of cigarette beetles in a suction light trap operated in each warehouse. After the first application of spray, the weekly catch dropped 78 per cent in the warehouse sprayed with lindane, and 89 per cent in the warehouse sprayed with pyrethrum.

THERMAL AEROSOLS, OR FOGS.—Three tests with lindane-oil thermal aerosols, or fogs, were conducted in closed-type warehouses containing cases of cigar filler /binder tobacco. Cages of cigarette beetles or tobacco moths were placed in the warehouses at random locations, at heights ranging from floor level to 10 to 12 feet above the floor. The fog generators which were used in all tests, were kept outside the building, and the aerosol was blown into the warehouse through a door. In the first test, where only one floor (about 72,000 cubic feet) of a relatively small warehouse was treated, the fog was introduced through a single door. In the other two tests, where large, one-story warehouses were used, the fog was introduced through two doors, on opposite sides of the building. After an exposure of approximately 2 hours, the doors were opened and the warehouse was ventilated for an hour or more before the cages were removed.

Test 1.—Lindane-oil containing 2 per cent of lindane was applied at a dosage of 100 ml. per 1000 cubic feet. The air temperature was 84° F. Ten cages, each containing approximately 25 cigarette beetles, were placed in the warehouse and exposed to the aerosol for 105 minutes. All the cages were fully exposed to the aerosol except one that was placed on the floor and under a wide board. After exposure, the test insects were transferred to other cages and held for observation.

The mortalities of cigarette beetles ranged from 35 to 100 per cent, and averaged almost 88 per cent. The mortality of the unprotected beetles in the air space probably approached 100 per cent.

Test 2.—A warehouse having a capacity of approximately 500,000 cubic feet was fogged with lindane-oil containing 2.5 per cent of lindane. The dosage was 60 ml. per 1000 cubic feet of air space, and

the air temperature was 86° F. Fourteen cages—10 containing approximately 25 cigarette beetles each and 4 containing 25 tobacco moths each—were placed at random locations throughout the warehouse. All the cages were fully exposed to the aerosol for 2 hours, except for one cage of beetles located on the floor under a case of tobacco. After the building was aerated for an hour the test insects were removed for observation.

The mortalities of the tobacco moths were high but were not 100 per cent. The mortalities of the cigarette beetles were almost negligible, the average being only 20 per cent. Mortality of cigarette beetles was complete only in one cage which was near the door where the aerosol was introduced and received the full blast from the fog generator.

Test 3.—The conditions of this test were the same as those for test 2, except that the dosage was 100 ml. per 1000 cubic feet of air space and the air temperature was 80° F. Some cages were fully exposed, some were in a narrow space between cases of tobacco, and one cage of beetles was on the floor under a case of tobacco. After the cages were removed from the warehouse they were placed in a cardboard carton with some check cages containing insects that had not been exposed to the aerosol, and left overnight. Other check cages were not placed in this carton. The next morning, 15 to 16 hours later, the insects were examined and the living ones were removed to other cages for observation.

The mortalities of the cigarette beetles exposed to the aerosol ranged from 20 to 100 per cent and averaged 85 per cent. All the tobacco moths were killed. Coverage of the warehouse by the aerosol was not so complete as casual observation of a fogging operation would indicate. There were differences in the mortalities of cigarette beetles in cages at different locations. The mortalities were lower in the more protected cages, an indication that there was little penetration of the fog into cracks, crevices, or other confined spaces.

The insects in the check cages left over night in a box with the exposed cages were apparently affected by fumes of insecticide from the treated cages. All the tobacco moths in the box were killed, although the mortality of moths in check cages held outside the box was only 2 per cent. Cigarette beetles were more resistant, as only 22 per cent were killed. This fumigation effect should be of definite value in tight buildings. Prolonged exposure in a treated building might show increased mortality of insects in protected spaces, and might counteract the lack of penetration into confined areas noted when cages of test insects were removed from a warehouse soon after exposure.

EFFECT OF LINDANE ON TOBACCO.—*Space Sprays.*—In an effort to learn the effect of lindane upon flue-cured tobacco, samples of leaf tobacco protected by a simulated wooden hogshead (made of hogshead staves) were exposed to 20 applications of lindane-oil space spray. The applications were made at 3- to 6-day intervals over a period of 10 weeks. The spray contained 2 per cent of lindane and was applied at an excessive dosage of 200 ml. per 1000 cubic feet. The tobacco used was 2 years old, and of a good grade—B2F. One lot of the same tobacco, not exposed to the spray, was held as a check.

Two weeks after the last application, samples of the sprayed and unsprayed tobacco were submitted to leaf-tobacco experts of two large cigarette manufacturers for evaluation as to any difference in aroma, flavor, appearance, or smoking quality. After extensive tests they concluded that the appearance and flavor of the sprayed tobacco were normal, but that there was a very slight depressing or masking of the natural aroma. This effect was so slight, however, that it was deemed unimportant. A test panel of experts from one of the companies could detect no appreciable difference in the smoking quality of cigarettes made from sprayed and unsprayed tobacco. A panel from the second company detected a slight difference—a very mild objectionable flavor in the cigarettes made from sprayed tobacco. Under conditions of commercial spraying of warehouses, where relatively small quantities of contaminated tobacco would be diluted with a high proportion of unaffected tobacco, it is possible that the abnormal taste would be even less noticeable. However, experts failed to detect any difference in the smoking quality of tobacco when it was exposed to the spray without protection and when it was protected by a wooden hogshead.

THERMAL AEROSOLS.—During the summer of 1950 a tobacco company treated

warehouses of flue-cured tobacco in hogsheads with a thermal aerosol containing 2 per cent of lindane, 3 per cent of chlordane, and 95 per cent of oil. Twenty weekly applications were made with a fog machine, all at a dosage of approximately 48 ml. per 1000 cubic feet of air space. Approximately a month after the last application, samples of the same grade of tobacco—C1L and C2L mixed—were taken as follows: One sample from the perimeter of a hogshead of tobacco from a treated warehouse, one sample from the center of a hogshead of tobacco from a treated warehouse, and one sample from a hogshead of tobacco from an untreated warehouse. A panel of leaf-tobacco experts was unanimous in recording an "off" odor for the untreated tobacco, and a "low in aroma" rating for the tobacco from the perimeter of a treated hogshead. The tobacco from the center of a treated hogshead was rated as "full, normal aroma." These ratings would seem to indicate that the untreated tobacco was a poor selection as a check, and that the objectionable odor was attributable to extraneous factors not connected with the test.

In a test of smoking quality, a panel showed a pronounced preference for the cigarettes made from untreated tobacco and from treated tobacco from the perimeter of the hogshead. This would seem to indicate that the smokers based their judgment on factors other than the effect of the insecticide. The tobacco from the center of a hogshead was not exposed to the insecticide and should have been comparable to the untreated check; yet it was judged the worst of the three lots. The tobacco from the perimeter of a hogshead was exposed to the spray, yet it was judged comparable to the untreated check and superior to the unexposed tobacco from the center of a hogshead. Evidently no effect of the insecticide on the smoking quality of the tobacco was detected.

INSECTICIDE RESIDUES.—Samples of tobacco exposed to the 20 applications of either the lindane-oil spray or the lindane-chlordane-oil thermal aerosol were analyzed for insecticide residues.

Unprotected flue-cured leaf tobacco exposed to the lindane-oil spray showed 41.6 p.p.m. of organic chlorine, or the equivalent of 56.58 p.p.m. of lindane. Tobacco in a box made of hogshead staves—a small-scale simulated hogshead—exposed to the lindane-oil spray, showed 62.9 p.p.m. of organic chlorine, or the equivalent of 85.54 p.p.m. of lindane. Untreated tobacco of the same lot and grade showed 53.2 p.p.m. of organic chlorine, or the equivalent of 72.35 p.p.m. of lindane. It is evident therefore, that there was no significant difference in the organic chlorine content of the sprayed and the unsprayed tobacco.

A sample of flue-cured leaf tobacco taken from the perimeter of a hogshead—directly under the wooden case that had been exposed to the lindane-chlordane-oil thermal aerosol—showed 20.0 p.p.m. of organic chlorine. A sample of tobacco from the center of a hogshead exposed to the aerosol showed 21.9 p.p.m. of organic chlorine. An untreated check sample of the same tobacco showed 16.1 p.p.m. of organic chlorine. Again it is evident that there was no significant difference in the organic chlorine content of the untreated tobacco and the tobaccos exposed to 20 applications of aerosol.

SUMMARY.—In 1950 various experiments were conducted with lindane in oil as a contact insecticide against tobacco moth, *Ephestia elutella* (Hbn.), and the cigarette beetle, *Lasioderma serricorne* (F.).

In a series of laboratory tests a space spray containing 0.25 per cent of lindane in oil killed 100 per cent of the tobacco moths when applied at a dosage of 100 ml. per 1000 cubic feet. A 2-per cent spray killed 84 per cent of the cigarette beetles and a 3-per cent spray killed 95 per cent.

In a single warehouse-scale test, at a dosage of 100 ml. per 1000 cubic feet, an oil space spray containing 2.85 per cent of lindane was approximately as effective against the tobacco moth and the cigarette beetle as a spray containing 0.89 per cent of pyrethrins.

In three warehouse-scale tests lindane-oil thermal aerosols, or fogs, containing 2 to 2.5 per cent of lindane, when used at a dosage of 100 ml. per 1000 cubic feet of air space, were effective against the tobacco moth and the cigarette beetle. At a dosage of 60 ml. per 1000 cubic feet they were not effective against the cigarette beetle.

When flue-cured tobacco was exposed to repeated heavy applications of lindane-

oil space sprays, the aroma and the smoking quality of the tobacco were only slightly affected. However, the effect was not sufficiently noticeable to be considered important.

When flue-cured tobacco was exposed to repeated applications of lindane-chlordane-oil thermal aerosol, or fog, the masking or depressing effect on the aroma of the exposed tobacco was so slight as to be considered negligible. No effect on the smoking quality of the tobacco could be detected that could be attributed to the insecticide.

A chemical analysis of tobaccos exposed to lindane-oil space sprays and to lindane-chlordane-oil thermal aerosols failed to show any appreciable difference in the organic-chlorine content of the treated and the untreated tobacco.

The Significance of *Anopheles* Species Complexes in Problems of Disease Transmission and Control

LLOYD E. ROZEBOOM[1]

Malaria is primarily a household disease, as transmission is ordinarily effected by species of *Anopheles* mosquitoes which enter houses to feed upon man. A species is dangerous in direct proportion to the degree of its development of two instincts; its predilection for man as a source of blood, and its desire to enter houses to feed and rest. There are a few exceptions; for example, *A. bellator* in Trinidad which feeds out of doors rather than indoors, and *A. minimus flavirostris* in the Philippines, which is said to rest not at all or only momentarily within the house after it has had a meal of blood.

The phenomenal success of DDT in malaria control has been due to the fact that the degree of domesticity exhibited by an *Anopheles* species also determines its chance of contact with a residual insecticide on the inside walls and ceilings of a house. The more dangerous the mosquito, the more likely it is to be killed by the residual insecticide. As a result, we have witnessed the steady decline of malaria in every region where DDT control programs were put into operation. The importance of this method lies in its adaptability to tropical rural areas, where formerly conventional methods of control were often of little value.

In view of the effectiveness of DDT, regardless of the species of *Anopheles* involved, there would appear to be no further need for detailed taxonomic, biological, or ecological studies on these insects. The practical malariologist could summarize the solution of anopheline-borne diseases in two words—"Apply DDT." Nevertheless, basic studies on the anophelines undoubtedly will be continued, in the first place because there are some investigators who are interested in various aspects of taxonomy and biology of the mosquitoes regardless of immediate practical applications; secondly, some mosquitoes are useful experimental animals which can be utilized in pursuit of solutions to fundamental biological problems; and in the third place, because there are people who foresee a continued need for basic research in spite of the present success of DDT.

The need for an ecological approach to control problems was brought out in the 1950 meetings of this Association at Denver. Ripper *et al.* (1951) discussed the increase in the proportion of pests to beneficial insects following partial destruction of both through the use of insecticides, and also the development of insecticide resistant strains. Ullyett (1951) pointed out that the differential effect of the new insecticide upon the various species in the environment, and the appearance of resistant strains, could be "responsible for the appearance of new pests or an intensification of problems presented by the old," and that we should work with the forces of natural control rather than against them.

Although DDT resistance has appeared in certain species of mosquitoes, at present this has not yet become a serious problem with respect to the anophelines. But enough should be known of the habits of a

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vector species to furnish an idea as to whether a residual spray would be highly effective, only partially so, or a waste of effort and money. In the present discussion we are less concerned with these obvious considerations than with the possibilities of a relationship between control measures and basic research on problems that appear to be about as far removed as possible from the applied field. This research is concerned with the mechanisms of evolution by which subspecies and species of mosquitoes arise.

Within the genus *Anopheles*, there are several groups of closely related species and subspecies; these are forms which diverged from one another comparatively recently to attain specific status, or which may still be in the process of doing so. Huxley (1943) defines four main types of species: (1) those arising through successional changes of a given stock; (2) those appearing suddenly through large mutational divergence; (3) geographical species which diverge following the isolation of two or more populations of a widespread species into geographical regions separated by physical barriers; and (4) ecological species which arise as the result of selection by certain populations of different ecological niches within a single geographical area. We seem to have no information concerning the role of successional divergence or sudden large mutations in the formation of mosquito species; furthermore, as noted by Bates (1949), we have little evidence of ecological speciation. The closely related species of *sabethine* mosquitoes may have separated as a result of selection of different types of water-holding plants as breeding sites. The *Anopheles* complexes with which we are concerned appear to have undergone geographical speciation. Our interest in these groups lies in the fact that through comparative taxonomic, physiological, ecological, and genetical studies it may be possible to arrive at an understanding of the evolutionary mechanisms involved.

The most thoroughly studied of the *Anopheles* groups is the *A. maculipennis* complex of the Palearctic Region, which contains seven species and subspecies. A map of their distribution (Fig. 1.) shows that although there is some overlap of ranges, there is evidence of geographic replacement. It is especially interesting to observe this in the closely-related *labranchiae* and *atroparvus*, and in *melanoon* and *subalpinus*, which are also so closely related that they are considered by some workers to represent subspecies rather than species. Those species with broadly overlapping ranges may have been separated from one another at one time and had diverged to such an extent that by the time they again came into contact, they retained their specific identities. The members of this complex are recognizable with certainty only by the pattern of the eggs; biologically they differ in selection of breeding sites, in host preferences, and in sexual behavior, and Bates (1939) has demonstrated varying degrees of sterility resulting from cross breeding of *atroparvus* males with females of the other species.

In North America there are five species which are members of the *maculipennis* "Artenkreis." The map of their distribution shows that essentially they inhabit different geographical areas. Of these, *Anopheles earlei*, which has the most extensive and most northerly distribution, appears to be the most closely related to the typical form of *maculipennis* of the Palearctic Region. The eggs of the two species are similar in appearance but are unlike those of any of the other Palearctic or Nearctic species. *A. earlei* may represent a New World extension of typical *maculipennis*, but they have been separated long enough for certain differences to develop. Recently I was able to observe mating of *A. earlei* in the laboratory in cages with an inside capacity of only 647 cubic inches; *A. maculipennis*, on the other hand, is said to require a very large cage; one used by Bates & Hackett (1939) in their mating experiments was 5 m. wide, 10 m. long, and 6 m. high.

Morphologically the North American species can be separated much more readily than can the Palearctic forms, but they are closely enough related to be utilized as experimental animals in studies on the mechanisms of speciation, and for this purpose, we have been maintaining colonies of *Anopheles quadrimaculatus*, *A. freeborni*, and *A. aztecus* in our insectary. One of my students, Ralph Barr, has found that although cross breeding occurs quite readily between these species, *A. quadrimaculatus* females, fertilized by males of *aztecus* or *freeborni*, produced inviable eggs or greatly weakened larvae which for the most part died in the first

or second stages. The few which reached the third instar died shortly thereafter. Similar results were obtained with females of *A. aztecus* or *A. freeborni* fertilized by *A. quadrimaculatus* males. A single hybrid male was obtained from a *freeborni* female; this was the only specimen that developed beyond the third larval instar. *A. aztecus* and *A. freeborni* are much more closely related to one another than they are to *A. quadrimaculatus,* as shown by the fact that cross breeding resulted in the production of F_1 hybrid adults. However, these adults represented only a small percentage of the numbers of eggs laid; high larval mortality showed that the hybrids lacked the vigor of the parent strains.

Cross fertilization occurs readily when males of one species are placed in a cage with females of another species, but in work now in progress we are attempting to determine whether, if given a choice, the males prefer to mate with females of their own kind. This work may be illustrated by the following experiment. Twenty-five male *quadrimaculatus* were placed in a cage, 1 cubic foot in size, with 25 female *quadrimaculatus* and 25 female *freeborni.* At the same time 25 male *freeborni* were placed in a similar cage with 25 females each of *quadrimaculatus* and *freeborni.* The mosquitoes were about 48 hours old at the time the experiment was begun, and they were kept in the breeding cages for 3 or 4 days. It was desirable to obtain a male to female ratio which would result in approximately a 50 per cent fertilization of the females, in order to avoid the obscuring of possible selective mating through too high male pressure. At the end of the 3 or 4 day period, the females were dissected and the spermathecae examined microscopically for the presence of sperm. This experiment was repeated four times, and the results are summarized in table 1, which shows that the males mated selectively with females of their own species. The males of *freeborni* were less selective than were those of *quadrimaculatus;* nevertheless there was a significant difference in the numbers of *freeborni* and *quadrimaculatus* females which were fertilized by the *freeborni* males.

Barr (1951) has also demonstrated differences in the responses of the three species to temperature; larvae of *Anopheles aztecus* were most susceptible to high temperatures; those of *A. freeborni* were less susceptible, and those of *A. quadrimaculatus* were the most resistant. Such differences might be an expression of adaptation to climatic conditions in the separate ranges.

Following the segregation of geographically isolated populations within a species, adaptation to local ecological conditions, accompanied by natural selection, must be in operation constantly, affecting not only structure but also physiological functions and even instincts. Thus, among the anopheline complexes, one may observe behavioristic and physiologic differences between cryptic species or subspecies, and also among local populations within these taxonomic units. This should be especially noticeable among species with an insular distribution, and I was constantly reminded of this when I had the opportunity to observe slight differences in breeding, resting, and feeding habits, and in cage behavior, of the members of the *Anopheles punctulatus* group of species in various island localities within the Australasian region. Species with wide-spread continental distributions may also show local variations in habits. In the New World, *A. pseudopunctipennis* enters houses and feeds upon people in Mexico and in the valleys of the Andes mountains of South America, but it appears to do so very rarely in Central America, Venezuela, and the Windward Islands. It seems to me that a possible explanation of this phenomenon might be that there is sufficient biologic plasticity within the species to permit it to take advantage of man-built structures which could serve as resting places in the more arid portions of its range where suitable natural resting places would be reduced in numbers. This might lead to habitual feeding upon man in the domestic environment, and the transmission of malaria by *A. pseudopunctipennis* in Mexico and western South America.

In West Africa, *Anopheles gambiae* is divided into two populations, one of which breeds in fresh water, and the other in brackish water. These two are now generally considered to be good species, the former retaining the name *A. gambiae,* while the latter is referred to as *A. melas.* Recently Thomson (1951) has described another salt water form from East

Table 1.—*Anopheles quadrimaculatus* × *A. freeborni*.[1]

Males	Females				Difference	
	Q		F			
	No. Dissected	Per Cent +	No. Dissected	Per Cent +	Per Cent	p
Q	79	68.2	77	6.5	61.7	<.001
F	75	34.7	75	80.0	45.3	<.001

[1] Per cent of fertilization of females under conditions allowing selection of the females by males. Four replications, each with 25 males in contact with 25+25 females for 3 or 4 days.

Africa, which appears to be different from *A. melas* of the west coast, and Thomson suggests that the two forms evolved independently. Presumably, through isolation and adaptation, they separated from *A. gambiae* or a pre-*gambiae* ancestor.

One example which is of especial interest to me is the difference in domesticity exhibited by *Anopheles bellator* in Trinidad and in Brazil. In Trinidad, this dangerous malaria carrier could not be found resting in houses (Rozeboom & Laird, 1942). In spite of the fact that this mosquito greatly prefers man to animals as a source of blood meals, we noted that relatively few individuals would enter houses to feed, and these appeared to leave immediately after engorgement. Most feeding took place out of doors. In the south of Brazil, where *A. bellator* and a close relative, *A. cruzii*, are also responsible for a great deal of malaria, these species enter houses and rest in them in large numbers (Rachou & Lima, 1950).

Additional examples could be given which would indicate that speciation in the anophelines involves geographic separation accompanied by adaptation and natural selection within local environments. In fact, domesticity and habitual feeding upon man may themselves be the result of adaptation of originally wild species to an environment created by man. This brings us finally to the possible relationships between an understanding of evolutionary mechanisms and practical mosquito-borne disease control through the use of residual sprays.

The great effectiveness of these residual insecticides is due to the fact that they bring about an alteration of the mosquitoes' environment. What was formerly an integral part of the ecological niche to to which the domestic species had become adapted, has become a lethal trap. But although this has brought about a tremendous destruction of the dangerous *Anopheles* species, especially in the case of *A. darlingi*, we still lack proof that this method alone will completely eradi-

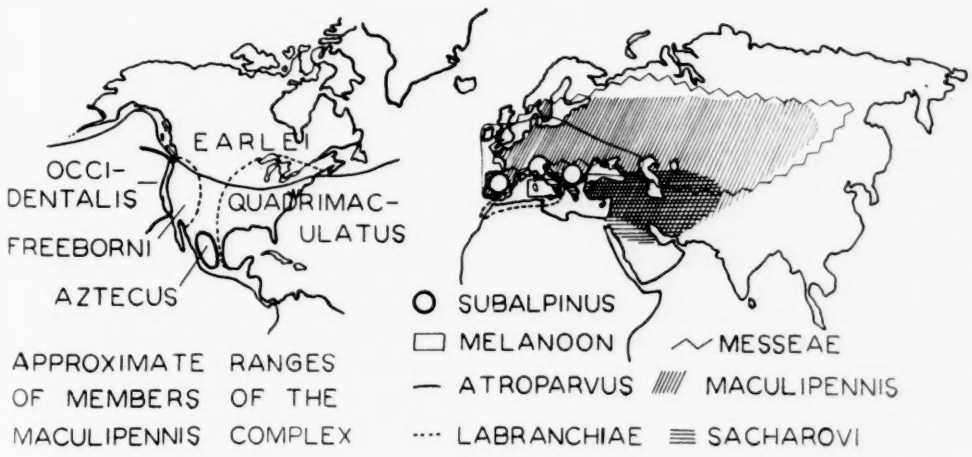

FIG. 1

cate an indigenous species within a widespread area. The campaign against *A. labranchiae* in Sardinia would appear to demonstrate this; in spite of several years of intensive anti-larval and anti-adult measures, the mosquito is still found, in greatly reduced numbers, but nevertheless apparently at a survival level. Survival is possible because there are a few adults which either do not enter houses for feeding and resting, or, if they do, escape without sufficient contact with the insecticide to cause their death. This may be purely a matter of chance, but it is of interest at least to speculate upon the possibility that these individuals are responding to altered ecological conditions which will lead through adaptation and natural selection, to the development of *Anopheles* strains which will be more or less completely adjusted to an environment in which houses are routinely sprayed with residual insecticides. Such strains might come to avoid houses entirely for feeding and resting, or, if they were to enter houses to feed, they might leave immediately with a minimum of contact with walls and ceilings, just as *A. bellator* does in Trinidad. One may wonder also as to the possibility of a change in the site of transmission of malaria and other diseases from indoors to out of doors, in which case residual insecticides would become entirely ineffective for the control of these diseases.

We have noted that anopheline species do alter their house-haunting as well as other habits in different localities, presumably in response to varying ecological conditions, and since extensive use of residual insecticides causes an altered ecological environment, we should at least be aware of the evolutionary plasticity of the insects which may allow an adjustment in their biology, which might cause, in Ullyett's words, an "intensification of problems presented by the old [pests]."

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A Corn Plant Maturity Index for Use in European Corn Borer Ecological and Control Investigations

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The effect of maturity of the corn plant on infestation and damage by European corn borer, *Pyrausta nubilalis* (Hubn.), was observed by Jablonowski (1898) many years ago. Several investigators—Beard (1943), Schlosberg *et al.* (1939), and others—have noted that on corn in pre-tassel stages of development the rate of corn-borer survival is in some way associated with the maturity of the plant, and it is quite generally agreed that corn-borer survival is highest on plants in the more advanced stages of development. The studies reported in this paper were designed to determine the efficiency of a new method of indexing the growth and maturity of a corn plant.

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Preliminary investigations on corn-borer survival and insecticide investigations for the control of first-generation corn borers were correlated with these plant-growth and maturity studies.

GROWTH STAGES IN DEVELOPMENT OF THE CORN PLANT.—The growing period of a corn plant may cover anywhere from 75 to 120 days. During this developmental period the plant gradually increases in maturity until harvest or death terminates its growth. The developmental period may be divided into growth stages, each stage being characterized by external morphological features, internal physiological changes, or change in chemical composition. The number of growth stages recognized, description of these stages, and terminology applied to each stage varies among different workers.

Bonnett (1948) and Leng (1951) have described three definite stages or growth phases during the development period of the corn plant. During the first or vegetative phase, differentiation of vegetative parts occurs. This phase is terminated when elongation of the growing point indicates the beginning of tassel differentiation. The second, known as the reproductive phase during which the development of reproductive structures takes place, commences with tassel initiation and is completed when sexual maturity is reached. The third phase begins with fertilization and extends through the period of seed development and is referred to as the seed-development phase. The classification of these two agronomists is based on the nature of gene action during growth.

Batchelder (1949) has divided the developmental period of a corn plant into 12 stages: pre-whorl, early-whorl, mid-whorl, late-whorl, early-green-tassel, mid-green-tassel, late-green-tassel, early-silk, mid-silk, late-silk, roasting-ear, and mature-ear. His classification is based on external morphological characters and his terminology is self-explanatory. Beard (1943) has added one, the seedling stage, to this classification.

TASSEL RATIO AND CORN DEVELOPMENT.—To meet the requirements of biological studies involving the correlation of insect development with growth of the corn plant, the writers set out to find a more exact method of designating specific points during the development of the plant. Apple (1948), while working on this same problem, conceived the idea that tassel development might be used as a criterion of maturity; unfortunately he did not pursue it far enough to develop its full value. He found, while experimenting with the idea of using the relationship between height of tassel and height of plant, that a very accurate indication of maturity of the plant could be obtained at any point after the tassel bud had appeared in the base of the plant. The formula for computing this tassel height-plant height ratio is as follows:

$$100\,\frac{(TH)}{(PH)} = Tr$$

where *TH* represents distance from base of plant to tip of tassel bud; *PH* represents distance from base of plant to tip of longest leaf extended, and *Tr* is the tassel ratio index.

To determine the height of the tassel before it has become visible at the top of the plant, it is necessary to split the plant lengthwise and expose the developing tassel bud. The readings to be made in calculating a tassel ratio are illustrated in figure 1. This ratio method of determining the maturity of a corn plant is restricted to use during the second phase of plant development as described by Bonnett, and will be most useful during the period between the time of tassel initiation and sexual maturity or anthesis of the plant. A comparison of tassel-ratio values with other corn-plant-growth characteristics frequently used to describe sweet corn plants in stages between tassel initiation and anthesis are given in table 1.

A comparison of the three methods of classifying growth stages of the corn plant will reveal the advantage of using the tassel-ratio method. Bonnett and Leng, agronomists, employ only one classification, "the reproductive phase," to cover the entire period of growth from tassel initiation to anthesis. Beard and Batchelder, entomologists, subdivide this development phase into six growth stages: early-whorl, mid-whorl, late-whorl, early-green-tassel, mid-green-tassel, and late-green-tassel. The tassel-ratio method of defining the maturity of a corn plant divides the developmental phase, beginning with tassel initiation and ending with anthesis, into approximately 90 units (tassel ratios 1 to 90). A corn plant will begin silking before a tassel ratio of 90 is reached.

Table 1.—Characteristics of plant development of Golden Cross hybrid sweet corn planted May 14, 1951.

Days from Planting	Number of Leaves		Plant Height[3]	Tassel Height	Tassel Ratio	Days to Tasseling
	Developed[1]	Visible[2]				
38	4.7	9.0	30.5	1.7	5.7	20
39	4.7	9.1	30.1	1.8	5.9	19
41	4.7	9.9	33.6	2.5	7.5	17
44	5.8	11.6	40.3	5.5	13.6	14
45	5.9	11.5	38.8	5.5	14.1	13
46	5.4	10.7	40.1	6.5	16.3	12
47	5.9	11.7	42.7	8.4	19.6	11
49	5.5	11.3	46.0	11.1	24.1	9
50	6.8	12.5	47.6	16.0	33.6	8
51	6.3	11.7	47.2	17.4	36.8	7
52	6.2	11.4	46.3	19.1	41.2	6
53	7.2	12.3	49.4	20.2	40.8	5
54	7.0	12.4	50.5	22.8	45.1	4
56	6.5	11.9	54.2	27.5	50.7	2
57	6.4	11.8	53.4	27.1	50.7	1
58	6.9	11.8	56.6	31.1	54.9	Tassel
59	7.0	12.3	61.1	37.0	60.5	
61	8.1	11.9	61.0	37.4	61.3	
63	8.5	11.7	65.4	45.4	69.4	
64	9.7	11.4	73.5	56.8	77.2	
66	10.9	10.9	77.2	67.1	86.9	Silk

[1] Developed leaves—includes all leaves that showed a distinct line of juncture, the ligule, between the blade and the leaf sheath. Does not include the two primary leaves.
[2] Visible leaves—all leaf blades present including those fully developed to those showing only a tip above the edge of the whorl cup. Does not include the two primary leaves.
[3] Extended plant height in inches.

In published recommendations for the control of first-generation corn borers, the height of the corn plant frequently has been used as an index of plant growth. It would be convenient if, for a given variety of corn, plant height were perfectly correlated with plant maturity expressed as a tassel-ratio figure. In that event, all hybrid A corn plants having a plant height of 33 inches would have the same tassel ratio and maturity regardless of year, season, or influence of the soil. However, this is not the case. A 33-inch corn plant grown in 1949 did not necessarily have the same tassel ratio as did a 33-inch corn plant grown in 1950 or 1951. The data in table 2 show a comparison of tassel ratios and extended height obtained for sweet corn hybrids B and D in 1949, 1950, 1951. These data illustrate the fact that the height of a corn plant is a highly variable factor influenced by season, variety, and soil fertility. Plant height, therefore, is not a reliable criterion for measuring a physiological stage of development or plant maturity.

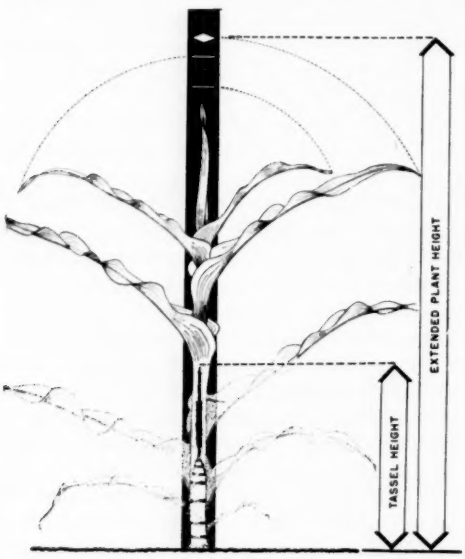

FIG. 1

Furthermore the data presented in table 2 by no means represent the extremes, since all of this corn was grown on very fertile soil and was highly fertilized. With a greater variation in soil-fertility level and other factors, we have found corn plants having a tassel ratio of 20 ranging from as low as 25 inches to as high as 55 inches in total extended height. In the year 1950 alone, individual plants of the same variety with a tassel ratio of 20 ranged from 30 to 50 inches in height.

Table 2.—Height and tassel-ratio comparisons on hybrid B and hybrid D sweet corn grown in 1949, 1950, and 1951.

HYBRID B SWEET CORN				HYBRID D SWEET CORN			
Extended height of plants	1949 Tassel ratio	1950 Tassel ratio	1951 Tassel ratio	Extended height of plants	1949 Tassel ratio	1950 Tassel ratio	1951 Tassel ratio
33	—	7	9	33	1	1	7
48	12	14	23	40	16	10	16
54	33	35	42	49	32	26	40
62	48	47	54	56	44	39	54
71	67	66	71	60	53	53	60
81	72	82	79	63	63	61	66

Batchelder (1949), using the same variety planted in different years, demonstrated that the number of days from planting date was not a reliable method of indicating a plant-growth stage. The data presented in table 3 substantiate the findings of Batchelder and indicate that there is no correlation between number of days from planting and plant maturity as measured by tassel ratio either where two varieties are planted at the same time or where the same variety is planted in different years. Similar differences can be shown for a single variety planted on different dates in the same year.

Batchelder (1949) characterized corn-plant-growth stages during the developmental period by indicating the number of leaf blades visible, number of rolled leaf blades composing whorl, and tassel appearance. This method of plant classification is very useful but lacks the refinement of the tassel-ratio method as illustrated in table 1. The method has the further weakness of considerable human error in taking readings. Even trained observers are seldom in complete agreement on the number of leaves present more than 40 per cent of the time.

Advantages of using the tassel-ratio method of indexing the growth and maturity of a corn plant have been described. The remainder of this paper is devoted to preliminary investigations on use of the method in survival studies of the Euro-

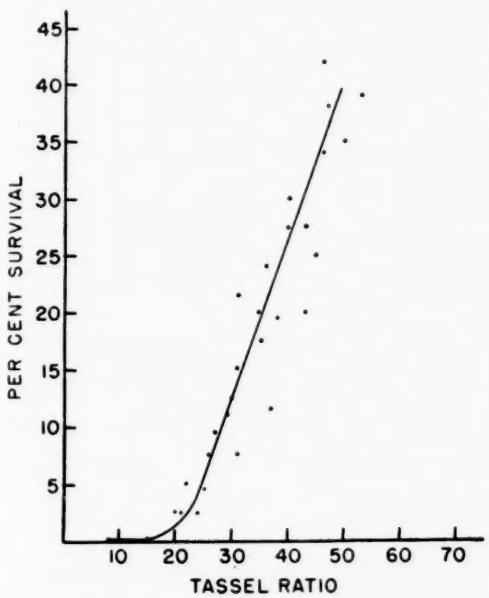

FIG. 2

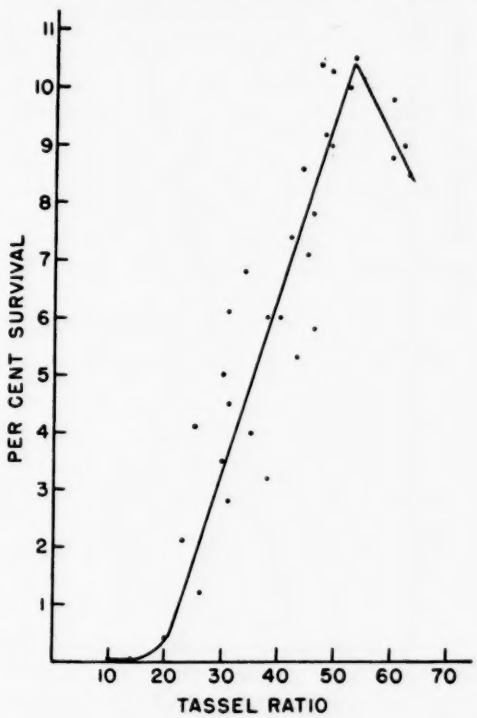

FIG. 3

Table 3.—Days from planting and tassel-ratio comparisons on two fields of hybrid A sweet corn in 1949 and 1950 and three fields of hybrid D sweet corn in 1949, 1950, and 1951.

Hybrid A Sweet Corn			Hybrid D Sweet Corn			
Days from planting	1949 Tassel ratio	1950 Tassel ratio	Days from planting	1949 Tassel ratio	1950 Tassel ratio	1951 Tassel ratio
40	17	—	48	15	23	16
43	30	17	52	33	25	29
46	48	24	54	48	41	45
49	56	42	58	67	57	58
52	62	54	60	72	64	66

pean corn borer and timing of insecticide treatments for control of first-generation borers.

Corn-Borer Survival.—Eight series of larval survival tests were conducted on sweet corn grown in the greenhouse and in the field. Corn borer egg masses were obtained from moths caged in the laboratory and the corn plants were manually infested by attaching blackhead masses to the undersides of corn leaves. The maturity of the plants at time of infestation was recorded by the tassel-ratio method. In two tests the actual number of eggs placed on a plant was recorded. In the remaining tests egg masses of uniform size were attached to the plants but no attempt was made to count the exact number of eggs. The experimental corn plants were dissected 20 days from the date of manual infestation and the number, instar, and location of all corn borer larvae found in each plant were recorded.

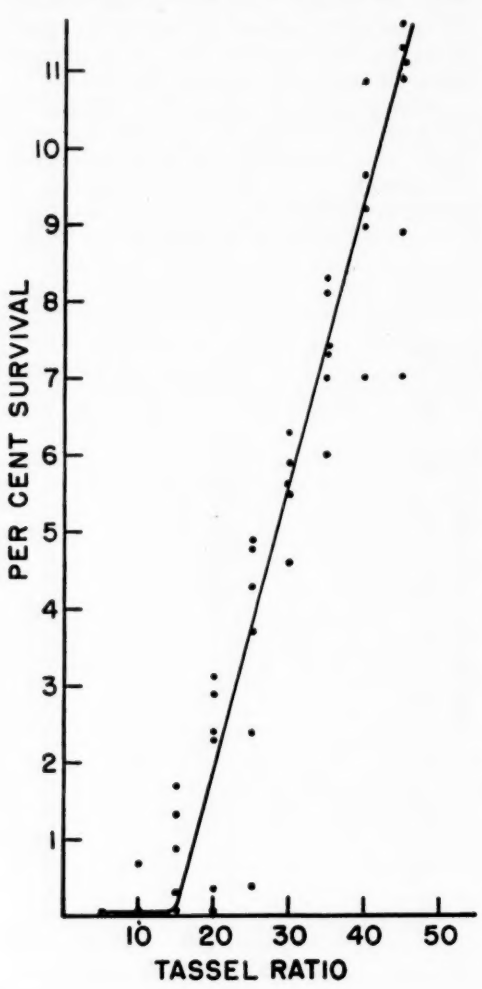

Fig. 4

The first series of survival tests was conducted in 1950 on hybrid A sweet corn grown in a greenhouse where the adverse effects of weather could be largely eliminated. The data in figure 2 indicate that survival of European corn borer larvae begins at a tassel ratio of about 20 and increases steadily thereafter. It should be noted that exceptionally high corn-borer survival is obtained under these conditions where adverse weather and predators are not important factors.

In the same year, corn-borer survival studies were conducted in the field on hybrid D sweet corn. Corn-borer moths

Table 4.—The range in tassel ratios to be expected during the early-whorl, mid-whorl, late-whorl, early-green-tassel, and mid-green-tassel stages of sweet corn plant growth.

Plant-Growth Stages	Ranges in Tassel Ratio
Early-whorl	5 to 23
Mid-whorl	20 to 46
Late-whorl	43 to 56
Early-green-tassel	52 to 72
Mid-green-tassel	68 to —

Table 5.—Number of days to tasseling on several varieties of sweet corn just entering the critical corn-borer-survival period. Observations in 1949, 1950 and 1951.

Sweet Corn Variety	1949		1950		1951	
	Tassel Ratio	Days to Tasseling	Tassel Ratio	Days to Tasseling	Tassel Ratio	Days to Tasseling
Hybrid A	17	9	19	9	—	—
Hybrid B	21	9	23	9	17	10
Hybrid B_1	—	—	20	10	22	9
Hybrid B_2	—	—	—	—	19	10
Hybrid C	—	—	22	9	—	—
Hybrid D	18	9	21	9	19	10
Hybrid D_1	—	—	20	9	19	9
Hybrid E	—	—	21	12	20	11

were not flying during the period these experiments were under way and the plants were free of outside infestation. Figure 3 indicates that here again borer survival began at a tassel ratio of 20 and increased until a high point was reached just prior to tasseling of the corn plant. This corn began tasseling at a tassel ratio of 58.

Six additional studies were completed in 1950 and 1951, using four different hybrids. The data obtained are so consistent that to save time and space all of the survival tests conducted in the field during 1950 and 1951 were averaged together and the data presented in figure 4. The data indicate that on the four varieties tested significant survival of corn-borer larvae begins with eggs hatching on corn having a tassel ratio of about 15 to 20.

Using the number of visible plant leaves and tassel appearance as criteria, Batchelder (1949) concluded that corn-borer survival began on corn in the mid-whorl stage. It seemed desirable to compare tassel-ratio figures with Batchelder's plant-growth stages for this critical survival period. This comparison is presented in table 4. As it was difficult to determine just when a growth stage ended and a new growth stage began, referring particularly to the early-whorl and mid-whorl stages, some imagination had to be used in comparing the two classifications. Assuming the comparison is fairly accurate, the data indicate Batchelder's conclusions were entirely right. However, since all of the changes in rate of survival occur in one or, at most, parts of two whorl stages, the Batchelder system could not bring out the relationship shown in figures 2, 3 and 4.

The number of days to tassel appearance, or the tasseling date, is a criterion frequently used by corn growers to express corn maturity. Surprisingly, many corn growers are capable of looking at corn in the mid- or late-whorl stages and predicting within 1 or 2 days the date on which that plant will show a tassel. Quite obviously Decker *et al.* (1949) considered the days to tasseling a good indication of borer survival when they

Table 6.—Comparison of single DDT spray treatments on hybrid A and B sweet corn in 1949 and 1950 and on hybrid D sweet corn in 1951.

1949				1950				1951	
Hybrid A		Hybrid B		Hybrid A		Hybrid B		Hybrid D	
Tassel Ratio	Borer Control	Tassel Ratio	Borer Control	Tassel Ratio	Borer Control	Tassel Ratio	Borer Control	Tassel Ratio	Borer Control
17	78%	6	75%	29	20%	8	57%	15	52%
30	78	15	88	39	32	11	77	16	63
48	82	33	93	49	76	23	78	40	75
56	74	48	97	61	52	38	87	49	89
62	55	67	72	69	44	46	91	59	71
78	71	72	70	76	48	58	80	65	63
Summary of best treatments									
48	82	48	97	49	76	46	91	49	89

recommended that only corn 10 to 14 days from tasseling be treated with insecticide for control of first-generation borers. In table 5 the number of days to tasseling on several sweet corn varieties is compared with tassel ratio. It is interesting to note that, regardless of season or variety, corn plants will be in the critical borer-survival period during the 9 to 12 days preceding tasseling. It might also be worth while to note that since most varieties of sweet corn will begin to show tassels at a tassel-ratio value of about 55. reference to figures 2 to 4 reveals the very great importance of survival the last 2 or 3 days before tassel appearance (tassel ratio 40 to 50).

APPLICATION OF INSECTICIDES.—In studying borer migration on the corn plant, Batchelder (1949) states that upon hatching the borers enter the whorl. They then accompany the tassel out of the whorl, and after the tassel branches droop, the borers leave the tassel to become established in the plant. Data already presented in this paper indicate borer survival of significance begins at a tassel ratio of approximately 15 to 20 and increases after that point. Theoretically, a larger percentage of the borers should be concentrated in the loosened plant whorl just prior to tasseling; water and dew penetrating the whorl will carry poisonous material to the larvae. To determine the validity of this thinking, insecticide studies were conducted to find the most opportune time for applying a single insecticide treatment. The data in table 6 show the per cent borer control obtained on sweet corn hybrids A, B, and D during 1949, 1950, and 1951. It will be observed in the summary at the bottom of the table that, regardless of variety or year, the most effective DDT insecticide treatment was applied between the tassel ratio of 46 and 49.

SUMMARY.—A technique is described for indexing the maturity of a corn plant during the developmental period after tassel initiation. This technique involves comparing the relationship between height of the tassel and height of the plant and expresses maturity of the plant as the tassel bud height-plant height ratio. The tassel-ratio technique is illustrated by the following formula:

$$100 \frac{(TH)}{(PH)} = Tr$$

where *TH* represents distance from base of plant to tip of tassel bud; *PH* represents distance from base of plant to tip of longest leaf extended, and *Tr* is the tassel ratio index.

While this method of indexing plant maturity can be used from tassel initiation to harvest or death of the plant, it is more practically adapted for use during the developmental period between tassel initiation and anthesis.

The advantages of the tassel-ratio index over other criteria used, such as height of a corn plant, number of days from planting date, number of visible and developed leaves, and whorl stages, are set forth and illustrated.

Through the use of the tassel-ratio technique as a method of indexing maturity of the corn plant it has been established that:

1. European corn-borer survival of significance begins at a tassel ratio of approximately 15 to 20.
2. Survival is highest on corn that will begin to show tassels in 1 to 3 days.
3. Sweet corn plants are in the critical borer-survival period during the 9 to 12 days preceding tasseling.
4. The most effective single application of DDT spray was applied when the corn plant had a tassel ratio of 46 to 49.

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Absorption and Metabolism of DDT, Toxaphene, and Chlordane by Resistant House Flies as Determined by Bioassay

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The absorption and metabolism of DDT by resistant house flies, *Musca domestica* L. have been determined by chemical analysis (Sternburg *et al.* 1950 and Sternburg & Kearns 1950) and by use of radioactive tracers (Lindquist *et al.* 1951). However, there have been no reports concerning the absorption or metabolism of other chlorinated hydrocarbon insecticides. Lack of a satisfactory chemical method of analysis or of radioactive insecticides has made it necessary to use biological assay to obtain such information on these insecticides. Tests with toxaphene and chlordane are reported in this paper. DDT was also included to permit comparison with the work cited above.

METHODS.—Lots of 50 female house flies of the ninety-fifth and ninety-sixth generations of the Orlando resistant colony were treated topically with solutions of DDT, chlordane, and toxaphene at the rate of 10 micrograms (μgm) of toxicant per fly. This colony had not been exposed to insecticides for several months. Twenty-four hours after treatment the flies were prepared for bioassay. Chlordane treated flies were also tested at 4 hours. After 24 hours the mortalities were 91, 100, and 98 per cent, respectively. The flies were then washed for 15 seconds in approximately 3 cc. of acetone to remove the toxicant remaining on the exterior. The flies were then macerated, and the toxicant was extracted with acetone and removed by filtration. The external wash and the filtrate from the internal extraction were reduced to dryness and then made up with acetone to volumes of 0.35 and 0.25 ml. respectively, for topical application to susceptible house flies.

One microliter of either the external wash or the internal extract obtained as described above was applied to each of 20 susceptible house flies. Tests were made in duplicate on any one day and four series of replicates were completed, giving a total of eight tests for each material. Mortalities determined after 24 hours were compared with those on a standard dosage-mortality curve prepared from the data obtained by treating susceptible flies with known amounts of the toxicants. The concentrations of solutions used in establishing the mortality curves ranged from 0.00625 to 0.2 per cent with at least five concentrations for each insecticide.

In the preparation of the standard dosage mortality curve the geometric mean was established for the mortalities at each dosage and plotted as a line graph with the per cent mortality as the Y axis and per cent concentration as the X axis. The mortalities obtained with the unknown solutions of the external washes and internal extracts were likewise computed for geometric means, and those means established on the curve of the appropriate standard. The theoretical concentrations of the unknown test solution were read directly from the X axis of the graph, and these percentage figures were converted to micrograms per microliter of solution. The latter figures were multiplied by 250 for an extract and by 350 for wash and then divided by 50 to give the demonstratable toxicant in micrograms per fly. The total recovered toxicant from wash and extract subtracted from the original individual dosage of 10 μgm is the theoretical amount of toxicant degraded by each fly. In some of the bioassays with chlordane fourth-instar floodwater *Aëdes* mosquitoes were used as the test insects instead of susceptible house flies.

TESTS WITH DDT.—The metabolism and absorption trends of DDT in house flies have been established by several workers. Sternburg, Kearns, and Bruce recovered 69 per cent of the dosage in the external wash, 3 per cent as DDT in the tissues (cuticle included), and 16 per cent as DDE (1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene) or DDA (bis(p-chlorophenyl)acetic acid) 17 hours after a topical treatment of resistant flies at the rate of 10 μgm per fly. Lindquist and coworkers were able to show a recovery from dead flies of 71 per cent of an applied 15 μgm in the external wash and 16

per cent in the internal extract. Approximately 65 per cent of the amount in the internal extract, or 1.5 μgm, was shown to be nontoxic (and therefore presumed to be metabolized) to mosquito larvae in bioassay.

The results of the present bioassay study compare favorably with these results. Of the original 10-μgm dosage 62 per cent was recovered from the external surface of the susceptible flies. Of the remaining 38 per cent, presumably absorbed, only 3 per cent proved to be toxic to the susceptible house flies. Therefore, approximately 35 per cent of the administered DDT must have been detoxified or lost to identification. Because of the many operations required to complete a test, no doubt this percentage includes a small percentage lost in transfers, incomplete extractions, or excretions.

The interference of extracted fat with the biological estimation of DDT has been reported (Bushland 1951) as one of the principal difficulties of the bioassay method. In these tests the degree of this interference was estimated by comparing by bioassay a known amount of DDT in acetone solution with a similar known amount added to 50 macerated house flies followed by extraction and filtration in the manner described above. Four tests showed an average of 21 per cent greater mortality for the solution containing only the DDT. However, as this interference applies only to the extracts, the results would be only slightly altered—i.e., the 24-hour extract of DDT would contain 0.36 μgm instead of 0.3 μgm and the toxicant metabolized would be reduced from 3.5 μgm to 3.4 μgm.

TESTS WITH TOXAPHENE.—The extract of the toxaphene-treated flies contained more unmetabolized chemical (1.4 μgm) than the extract of flies treated with DDT or chlordane, and the percentage of toxicant found in the wash was lower than in the wash of DDT-treated flies. However, the total recovery of toxic agent from both external and internal portions (60 per cent) was similar to that obtained with DDT. Four micrograms of the toxaphene was indicated to be detoxified per fly, which is slightly more than in the DDT-treated flies. It appears, therefore, that the resistant flies absorbed more toxaphene (5.4 μgm) than DDT (3.8 μgm) and that they retained more of the chemical in an unmetabolized state.

TESTS WITH CHLORDANE.—Tests with chlordane were conducted primarily to obtain information on the rate of absorption of this toxicant as indicated by unmetabolized chlordane in the flies. Bioassay showed approximately 0.4 μgm of chlordane to be present in each fly after 4 hours and about 0.6 μgm after 24 hours. It is indicated that, like DDT (Sternburg *et al.* 1950), the absorption of chlordane is most rapid within the first 4 hours after topical treatment.

In one test the toxicity of both the external wash and the internal extract was determined as an indication of the disposition of the total dosage. When extraction was made after 24 hours, only 4.1 μgm of unmetabolized chlordane could be accounted for, 0.9 μgm in the extract and 3.2 μgm in the wash. The remaining 5.9 μgm was either detoxified or lost to identification by other means. As it was necessary to retain these samples 72 hours before completing the test, a portion of the chlordane could have deteriorated although the samples were held in tightly corked vials. The recovery of 0.9 μgm of chlordane in the extract as compared with about 0.6 μgm in other tests probably indicates that no such loss occurred. When extractions were completed 4 hours after topical treatment, a smaller amount (0.4 μgm) was recovered in the extract and a greater amount (5.3 μgm) in the wash, which is to be expected since penetration of the toxicant through the cuticle probably continues after 4 hours.

The absorption of chlordane in resistant flies was studied further by using *Aëdes* mosquito larvae as the test insects. The resistant flies were treated with 0.5 μgm of chlordane and only those flies that were dead after 24 hours were used. Several tests showed on an average 88 per cent of the dosage to be absorbed and approximately 55 per cent of this to be metabolized. These figures are similar to the 68 per cent penetration and 58 per cent metabolism shown in the bioassay tests with house flies.

SUMMARY.—The absorption and metabolism of DDT, toxaphene, and chlordane in resistant house flies, *Musca domestica* L., have been studied by a bioassay method using adult female house flies and *Aëdes* mosquito larvae as test insects. Resistant flies topically treated with 10 μgm of the toxicant were rinsed externally

with acetone 4 or 24 hours after treatment, the flies were then macerated, and the absorbed toxicant extracted with acetone and removed by filtration. The mortalities obtained by topical treatment of susceptible flies with the extract were compared to a standard dosage-mortality curve obtained by treating susceptible flies with several known concentrations of insecticides. Resistant flies absorbed 5.4 μgm of toxaphene, 3.8 μgm of DDT, and 6.8 μgm of chlordane. The bioassay method indicated that resistant flies metabolized 4.0 μgm of toxaphene, 3.5 μgm of DDT, and 5.9 μgm of chlordane.

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The Comparative Toxicity of Some Organic Insecticides as Termite Soil Poisons

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In a previous article, the writer (1950) described a method for the evaluation of some organic insecticides as termite soil poisons. This report was of a preliminary nature and represented three years of testing work with a number of new insecticides. A high residual toxicity of the chemicals mixed with sandy soil was indicated early in the tests and, in general, this residual toxicity has continued. Chemicals that remained toxic for as long as three years are still residually toxic after more than five years of testing work. Further work will be needed to determine the time limits of residual toxicity of the insecticides in the soil. Results obtained after five years of work, indicate that several of the currently popular agricultural insecticides may be used to advantage for control of subterranean termites.

The testing technique has consisted of incorporating weighed amounts of the active insecticides into weighed samples of moist sandy soil. Formulations of the insecticides other than in petroleum oils were selected for preparation of the dilutions. In most cases, wettable powder formulations were used but dust or emulsion formulations of some insecticides were used because wettable powders were not available at the time of preparation. Glass battery jars, of approximately one gallon capacity were used as the test containers. The amount of soil used (100 ounces for each dilution) approximately half-filled a battery jar. A folded and moistened paper towel was placed on top of the soil in each battery jar. At intervals of approximately every two months, 10 large worker termites of *Reticulitermes flavipes* (Kollar) were introduced on the paper towel in each container. Observations of the insects were made each 24 hours after infestation for a period of 5 days. Information was obtained on the speed of action of the different insecticides at various dilutions.

The soil in the test jars has not been disturbed by stirring or mixing since the preparation of the dilutions. The jars containing the soil samples have been stored beneath a house built on piers when testing work was not in progress. Water evaporates from the soil during storage periods and favorable moisture conditions for the termites have been restored by addition of water to the soil prior to each test infestation.

Control jars of untreated soil have been infested with termites in an identical manner. In the control jars, and in jars of treated soil that was no longer toxic to the insects, the actions of the termites were normal and the soil was readily penetrated. In these cases, the cellulose of the paper towel served as food for the

Table 1.—Relative toxicity of insecticides on the basis of tests conducted over a period of five years. All dilutions are on the basis of one part by weight of the insecticidally active ingredient to the various quantities of sandy soil indicated.

Chemical	Dilution	Number of Times Infested	Days for 100 Per Cent Knockdown		
			1st Year	5th Year	All Years
DDT	1–200	31	4.7	3.0	3.0
TDE	1–200	31	4.2	3.5	3.3
TDE	1–1,000	31	5.0	4.3	4.2
Methoxychlor	1–200	31	3.5	2.0	2.3
Methoxychlor	1–1,000	31	3.9	2.7	3.0
BHC[1]	1–10,000	31	1.5	1.3	1.3
BHC	1–20,000	31	1.4	1.3	1.3
BHC	1–50,000	31	3.0	4.1	2.8
BHC	1–100,000	31	3.1	4.7	3.0
Chlordane	1–200	30	1.7	1.2	1.3
Chlordane	1–1,000	30	2.8	2.0	1.9
Chlordane	1–2,000	30	2.7	2.6	2.0
Chlordane	1–10,000	30	4.0	4.0	3.8
Chlordane	1–20,000	30	4.0	4.0	4.0
Toxaphene	1–1,000	29	3.4	2.0	2.2
Toxaphene	1–2,000	29	3.1	3.0	2.2
Toxaphene	1–10,000	29	4.1	4.5	3.7
PCP[2]	1–200	28	1.2	1.5	1.4
SPP[3]	1–100	25	1.4	2.0	1.3
SPP	1–500	25	2.0	2.0	1.6
SPP	1–1,000	25	3.0	2.7	2.7

[1] Benzene hexachloride, gamma isomer.
[2] Pentachlorophenol.
[3] Sodium pentachlorophenate.

Table 2.—Relative toxicity of insecticides on the basis of tests conducted over a period of approximately two years. All dilutions are on the basis of one part by weight of the active insecticide to the various quantities of soil indicated.

Chemical	Dilution	Number of Times Infested	Days for 100% Knockdown
Aldrin	1– 5,000	7	1.1
Aldrin	1– 10,000	7	1.0
Aldrin	1– 25,000	7	1.6
Aldrin	1– 50,000	7	1.4
Aldrin	1–100,000	7	1.4
Dieldrin	1– 5,000	7	1.0
Dieldrin	1– 10,000	7	1.0
Dieldrin	1– 25,000	7	1.1
Dieldrin	1– 50,000	7	1.0
Dieldrin	1–100,000	7	1.1
Heptachlor	1– 5,000	6	1.1
Heptachlor	1– 10,000	6	1.1
Heptachlor	1– 25,000	6	1.3
Heptachlor	1– 50,000	6	1.7
Heptachlor	1–100,000	6	1.7

termites and it was not unusual to find the insects still alive in these jars a month or more after infestation. Although the termites are reported to be negatively phototrophic, they frequently mine in the soil next to the glass of the battery jars and are not difficult to observe when beneath the surface. Obviously the little animals are more sensitive to desiccation than to light.

Coaton (1947) reported a repellent action of both benzene hexachloride and DDT against species of termites in South Africa. These species of termites differ greatly from species found in North America. The chemicals included in these tests have shown no indication of repellent action against the test insect at the dilutions indicated. The moistened paper towel has served as an uncontaminated medium for introduction of the insects into the test containers. Had a repellent action existed, the termites could have remained on the paper towel rather than move to the treated soil. In some cases the insects tunnelled into the treated soil only to die a short distance below the surface. Penetration of the soil was usually next to the glass and observations could be made easily.

According to Lyon & Buckman (1943) the weight of a cubic foot of dry soil is variable depending upon its mineral and organic content. This weight may vary from 70 pounds per cubic foot to 125 pounds per cubic foot. An average weight of 100 pounds, as the weight of a cubic foot of dry sandy soil, has been estimated by the writer. To prepare a dilution of one part of the active insecticide in 100 parts of soil, one pound of the active insecticide would be needed. Likewise, 0.1 of a pound of the insecticide would be needed per cubic foot to produce a dilution of 1–1,000 or 0.01 of a pound of insecticide per cubic foot of soil would produce a dilution of 1–10,000.

A number of dilutions of chemicals failed during the early months of the tests. Among these chemicals were: all dilutions of paradichlorobenzene; pentachlorophenol at dilutions of 1–2,000, 1–10,000, and 1–20,000; sodium pentachlorophenate at dilutions of 1–5,000 and 1–10,000; and toxaphene at dilution of 1–20,000. Other dilutions of these same chemicals and all dilutions of other insecticides tested have remained residually active during the full testing period.

During the course of repeated infestations of the treated soil samples, information has been obtained on the relative speed of toxicity of the various chemicals at different dilutions. Although rapidity of action is not fundamentally important for termite control work, this speed of action should serve as an index to the

relative toxicity of the chemicals to the test insect, *Reticulitermes flavipes* (Kollar).

In examining the table, it must be remembered that the infested jars of treated soil were examined only once each 24 hours over a period of five days after infestation. Temperature was one of the factors that contributed to differences in speed of action from one test infestation to another. However, this should not alter the results because each jar in each test infestation was handled under as near identical conditions as possible. Tests have been conducted under an open shed and temperature control has not been possible.

From the table it may be noted that at comparable dilutions methoxychlor is more quickly toxic than DDT and that DDT is more quickly toxic than TDE. Very early in the work it was noted that DDT and its analogs were only slowly toxic to the test insect as compared to other new insecticides. For this reason, further dilutions of these insecticides were not prepared.

It may be noted that the gamma isomer of benzene hexachloride is more quickly toxic than chlordane at comparable dilutions (1–10,000 and 1–20,000). Both of these chemicals are extremely toxic to the test insect. Substantiating proof of their effectiveness has been obtained by use of these insecticides on structures naturally infested with the test insect.

From the comparative data in the table it appears as though a 1–10,000 dilution of toxaphene is equally as effective as the same dilution of chlordane. A toxaphene dilution of 1–20,000 failed within 6 months after the dilution was prepared. Several naturally infested buildings have been treated with toxaphene at an estimated dilution of one part of toxaphene in 10,000 parts of foundation soil. Termite infestation persisted after such treatment and it must be concluded that toxaphene is not as toxic to the test insect as some other insecticides included in the test series.

Pentachlorophenol and sodium pentachlorophenate are quickly toxic to the test insect at dilutions of 1–200 and 1–500. However, it must be remembered that less concentrated dilutions of these chemicals, comparable to the dilutions of the gamma isomer of benzene hexachloride or of chlordane, failed during the early months of the tests. To produce a dilution of one part of pentachlorophenol in 200 parts of soil, one-half pound of the active insecticide would have to be mixed with a cubic foot of sandy soil.

Other promising new insecticides have been included in the test as they became available and aldrin, dieldrin, and heptachlor have been tested for approximately two years. All of these chemicals have remained residually active in the soil. Table 2 indicates the relative speed of action of these insecticides.

Further testing is needed for these compounds. However, present indications are that these insecticides will continue to give a relatively quick knockdown of the termites.

The new organic insecticides have the following advantages over older chemicals that have been used for termite control.

1. General availability from agricultural supply dealers.
2. Dilution with water rather than petroleum oils which are relatively expensive, toxic to plants, and may create fire hazards.
3. Low toxicity of the insecticides to plants.
4. High toxicity to termites permitting low dosage.
5. Lack of unpleasant and persistent odors.

SUMMARY.—On the basis of more than five years of testing work, gamma benzene hexachloride and chlordane have been found to be more toxic to the subterranean termite, *Reticulitermes flavipes* (Kollar), than pentachlorophenol, sodium pentachlorophenate, toxaphene, and DDT and its analogs. Aldrin, dieldrin, and heptachlor appear to be very promising on the basis of approximately two years of testing work.

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Fall Applications of Insecticides to Control Spittlebug Nymphs

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Under some conditions, springtime application of insecticides for the control of the meadow spittlebug, *Philaenus leucophthalmus* (L.), is undesirable. App & Everly (1950) showed that fall applications of insecticides for clover root borer control were effective in reducing nymphal spittlebug populations the following spring. These authors did not state whether such reductions were brought about by control of the adult or the numph. Weaver (1951b) showed that the seasonal behavior of adult spittlebugs made possible the reduction of spring populations of numphs by reducing fall populations of egg laying adults. The data presented here are designed to show the efficacy of such treatment.

Tests were started in the fall of 1948 to determine if insecticidal treatment of newly seeded legumes would allow meadow plants to enter the winter in better condition and therefore produce more abundantly the following spring. Replicated plots of alfalfa 45 by 150 feet were dusted with 1 pound of actual DDT per acre at three 2-week intervals starting on July 31, 1948. This treatment resulted in 70.6 per cent control of spittlebug nymphs on May 17 of the succeeding year and the treated alfalfa yielded 4510 pounds of baled hay per acre compared with 3699 pounds in the untreated check. Similar reductions in spittlebug infestations and increases in hay yields were evident in plots of red clover sprayed with DDT on August 12 and August 27, 1948. Treatment of new seedings of legumes in the fall therefore showed promise in increasing yields the following year, apparently by reduction of the spittlebug populations. Later tests were designed to establish definite times and dosages of materials to use.

Wilson (1949), Pielou (1950), and others have shown that DDT is one of the most effective of recently developed organic insecticides for reduction in numbers of adult spittlebugs. Several insecticides were tested on plots measuring 50 by 800 feet for the control of injurious insects on alfalfa grown for seed production in northern Ohio in 1949. All of the insecticides were applied in 100 gallons of water per acre on July 7. Dosage per acre for each material was: toxaphene, 1.5 pounds; aldrin, 0.53 pound; methoxychlor, 2 pounds; DDT, 1 pound; benzene hexachloride, 0.5 pound gamma isomer; DDT 1 pound plus chlordane, 1 pound; heptachlor, 0.55 pound; and chlordane, 1 pound. Sweep samples were taken periodically after treatment. Figure 1 shows relative populations in the various treatments compared with the check. DDT and methoxychlor were clearly the best of the materials tested for adult spittlebug control. Accordingly these two insecticides were used exclusively in the fall treatment studies.

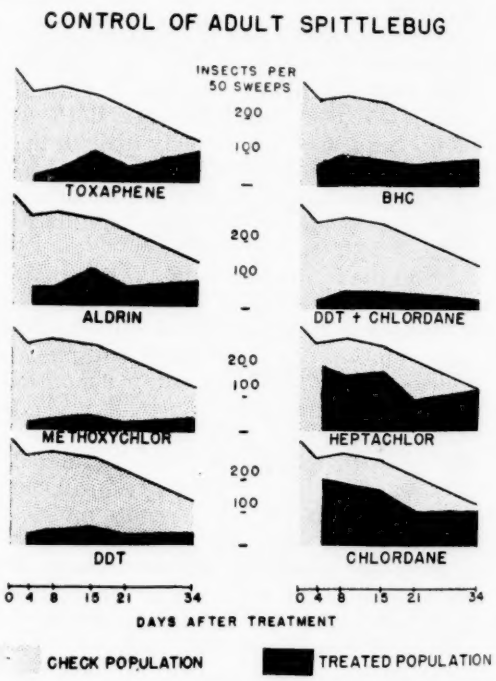

FIG. 1.

TESTS IN 1949.—In the following described tests, fall applications of insecticides were made during the year to meadow crops seeded in wheat or oats.

Test 1 included 1 and 2 pounds of DDT per acre applied at two different times to

replicated plots each 100 feet square in a mixed meadow containing alfalfa and red clover. The two concentrations of DDT were delivered in 100 gallons of water per acre on August 19 and September 2, 1949. Figure 2 shows the relative populations in the treated areas from August 19 to October 14. On May 15, 1950 a portion of the check plots measuring 13 by 100 feet was treated with .2

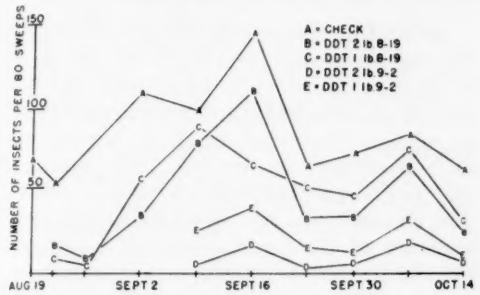

FIG. 2. Spittlebug control on new pasture seedings.

pound gamma benzene hexachloride per acre. Nymph counts were made on May 25. The spring time populations in the treatments are presented in table 1.

Table 1.—Per cent of stems infested by spittlebug nymphs following spring and fall applications of insecticides. Data collected May 25, 1950.

INSECTICIDE	DOSAGE PER ACRE	DATE APPLIED	INFESTED STEMS	CONTROL
DDT	1 lb.	8-19-49	38.7%	28.9%
DDT	2 lb.	8-19-49	21.0	61.5
DDT	1 lb.	9- 2-49	14.3	73.9
DDT	2 lb.	9- 2-49	3.7	93.1
γBHC	0.2 lb.	5-15-50	0.25	99.5
Check			54.5	

As shown by Chamberlin & Medler (1950) counts of infested stems represent a conservative estimate of the control obtained. Seventy-three and 93 per cent control based on infested stems, therefore, may be considered as adequate control. In this case the DDT sprays applied on September 2 were not as effective as spring application of benzene hexachloride but were sufficient to reduce the numbers of nymphs to a non economic level.

Test 2 was performed to evaluate one application as compared with two applications. DDT at 1 pound per acre was applied on August 8 in one instance and August 8 and 30, 1949 in another instance. The plots containing alfalfa measured 70 by 90 feet. The adult spittlebugs were sampled periodically. The per cent control of adults during the egg-laying period (September to November) is presented in table 2. Samples were taken by sweeping with a 15 inch net. Infested stems were counted on May 27, 1950 and the plots harvested on June 16 in the manner described by Weaver (1950). Infestation and yield data are presented in table 2. Judging from the sweep records and the yield data in this case, infested stem counts have shown a tendency to underestimate the control obtained.

Table 2.—Control of adult and nymphal spittlebugs by applications of 1 pound actual DDT per acre.

DATES OF APPLICATION 1949	CONTROL OF ADULTS 9-3 TO 11-1-49	INFESTED STEMS 5-27-50	CONTROL	YIELD HAY[2]
8-8 and 8-30	84.5%	18.5%	71.4%	5655 lb.
8-8	53.0	51.7	19.8	4930 lb.
Check	1.43 A/S[1]	64.5	—	4080 lb.

[1] Average adults per sweep for 10 sampling periods.
[2] 20 per cent moisture.

A comparable test was also conducted on plots of birdsfoot trefoil, a favorite host plant for the spittlebug. No infestation records were taken but yield of 20 per cent moisture hay for the twice sprayed plots was 5175 pounds, for once sprayed plots 4310 pounds, and for untreated plots 3980 pounds.

Test 3 included DDT, 1 pound per acre and methoxychlor, 2 pounds per acre applied to plots 200 by 150 feet in alfalfa on September 19, 1949. This date was considered as too late for effective control of the succeeding year's nymphs. Table 3 lists the results. Excellent control of adults was obtained with both materials but apparently about 50 per cent of the eggs had already been deposited prior to treatment.

Table 3.—Control of spittlebug nymphs by application of DDT and methoxychlor to control egg laying adults on September 19, 1949.

TOXICANT AND POUNDS PER ACRE	FALL POPULATION[1] 9-20 TO 11-7	ADULT CONTROL	INFESTED STEMS 5-27-50	CONTROL NYMPHS
DDT 1	0.039[2]	93.1%	16.8%	66.9%
None	0.56	—	50.8	
Methoxychlor 2	0.041	95.2	33.3%	46.3
None	0.855	—	62.0	

[1] Eight sampling periods.
[2] Adults per sweep of a 15 inch net.

Table 4.—Per cent control of spittlebug nymph populations after reduction of adults with 1.5 pounds actual DDT per acre (1951).

Date of Application 1950	Nymphs Per Stem 5-15	Control	Infested Stems 5-15	Control	Adults Per Sweep 6-10	Control
8-12	1.90%	7.0%	68%	—	17.35	21.6%
9-2	.34	83.3	21	61.8%	3.83	82.7
9-13	.53	74.0	32	41.8	6.98	68.4
Check	2.04	—	55	—	22.12	—

Tests in 1950.—Two methods of applying DDT were included in a test on alfalfa plots measuring 200 by 150 feet. A DDT wettable powder formulation was applied at 100 gallons per acre at 150 pounds pressure. A liquid formulation of DDT was applied at 9 gallons per acre at 30 pounds pressure. In both cases 1.5 pounds of actual DDT per acre was applied on September 3, 1950. On May 9, 1951 counts of nymphs per stem revealed 0.33 per stem in the low volume plots, 0.51 in the high volume, and 1.86 per stem in untreated checks. This was 82 and 72 per cent control. Differences between the two treatments were not statistically significant. Both treatments were different from the check.

In a second test, time and dosage were tested. For clarity the two items will be discussed separately. The plots measured 90 by 90 feet and were replicated four times. The crop was a mixed meadow crop with alfalfa predominating. Single applications of DDT at the rate of 1.5 pounds per acre were made to replicated plots on each of the dates, August 12, September 2, and September 13, 1950. Applications were made in 100 gallons of water per acre. The early treatment gave immediate reduction of the adults but reinfestation occurred two weeks after treatment. The sprays applied in September reduced the adult population and practically no reinfestation occurred.

Several methods were used for evaluating the resulting springtime infestations in these treatments. One method involved selecting 25 standing wheat straws at random from each of the four plots in each treatment on April 5, 1951. Spittlebug eggs were counted on these straws. The number of eggs represented a rough measure of the population; for example, the September 2 treatment contained 14 eggs on 100 straws compared with 242 eggs on 100 straws from the check. One hundred straws were not considered an adequate sample to discover fine differences, however.

Results of the other methods are given in table 4. Nymphs per stem and per cent infested stems were determined. These counts again confirmed Chamberlin & Medler's conclusion that the infested stem counts are a conservative estimate of the control obtained. A fourth measure is represented by the adults per sweep taken at the time of maximum emergence of adults from the spittle masses. This method has been described by Everly (1951). Close agreement between nymphs per stem and adults per sweep is evident.

Proper timing of the insecticide application is again emphasized in this test. Best control was obtained when the insecticide was applied at the beginning of egg development within the female.

Three separate dosages of DDT were

Table 5.—Per cent control of spittlebug nymph populations in 1951 after reduction of adults by different concentrations of DDT applied on September 2, 1950.

Concentration Actual DDT Per Acre	Nymphs per Stem 5-15	Control	Infested Stems 5-15	Control	Adults Per Sweep 6-10	Control
1 lb.	0.45	77.9%	28%	49.0%	4.31	80.5%
1.5 lb.	0.34	83.3	21	61.8	3.83	82.7
2 lb.	0.19	90.7	15	72.7	2.68	87.8
Check	2.04	—	55	—	22.12	—

employed in this same test. Since previous years' tests had shown the optimum time for treatment to be around the first of September, three dosages were applied on September 2. DDT at 1 pound, 1.5 pounds and 2 pounds of actual toxicant was used. Table 5 lists the results in terms of the three criteria used in table 4. Effectiveness of the treatment increased with increased dosage. The cost efficiency of increased dosages should be critically examined, however. As shown by Weaver (1951a), reduction of the springtime populations to below one-half bug per stem is probably sufficient to relieve the meadow crop from economic damage by the spittlebug nymphs.

SUMMARY —Where springtime applications of insecticides for spittlebug control are undesirable this insect may be reduced to noneconomic levels by treatment in the fall of new legume seedings to eliminate egg laying adults. In northern Ohio 1 to 2 pounds of actual DDT per acre applied the first week in September gave best control of succeeding nymphal populations. Treatments later in September gave decreasing control proportional to the time elapsed after the optimum date. Earlier applications gave poor control due to reinfestation of the fields prior to the time of oviposition.

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Methyl Eugenol as an Attractant for Oriental Fruit Fly

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In Hawaii methyl eugenol has been found to be extremely attractive to the male oriental fruit fly *Dacus dorsalis* Hendel. Its advantages include reasonably good specificity, non-repellency at high concentrations, and comparative non-toxicity to plant and animal life. As a result of investigations reported herein, methyl eugenol has been used in a limited way in the Panama Canal Zone, and it was adopted for use in a large-scale scouting program initiated in California in 1950. More recently explorers for fruit fly parasites in India and Borneo have utilized it to determine quickly if *D. dorsalis* is present in their vicinity.

The attraction of methyl eugenol to certain fruit flies is not a new discovery. Howlett (1912) first reported that oil of citronella was attractive to males of *Dacus diversus* Coq. and *D. zonatus* Saund. in India, and reasoned that since two species were involved possibly two separate ingredients were the attractants. Later Howlett (1915) found methyl eugenol, presumably a constituent of oil of citronella, to be attractive to *D. zonatus*, whereas *D. diversus* was most strongly attracted by iso-eugenol and *D. ferrugineus* F. by both methyl and iso-eugenol. The *D. ferrugineus* referred to is now considered by certain taxonomists[2] to have been *D. dorsalis*.

After the discovery of the oriental fruit fly in Hawaii in May 1946, and during its remarkably rapid increase and spread, Hawaiian entomologists tried oil of citronella (Ceylon) as an attractant. Because of its high attractiveness to the males, it was accepted as a standard for scouting and population studies.

[1] The writer is indebted to H. L. Haller for suggestions and assistance in the rapid procurement of several of the test materials.

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Soon after the Bureau's greatly expanded oriental fruit fly research program got under way in July 1949, the screening of both fermenting and nonfermenting attractants was initiated. Among the chemicals first screened were those such as methyl eugenol that had been found attractive to other fruit pests.

More than 4 million male oriental fruit flies were captured in the first 10 months of these tests.

PRELIMINARY TESTS.—The superior performance of methyl eugenol, as compared with that of citronella (Java and Ceylon) and also a fraction derived from it, was first observed where filter-paper disks wet with five drops of the test material were tacked to guava limbs. Most of the several hundred male flies attracted within 20 minutes went directly to the methyl eugenol.

Subsequently tests of some 60 chemicals were made with a series of 4-ounce wide-mouthed bottles exposed a few inches apart in traps. The position of the bottles was varied several times during a test, which was run for 3 to 7 days. The chemicals were emulsified in water and used at the rate of 2 ml. per bottle.

In one of these tests methyl eugenol caught 5490 oriental fruit fly males, methyl iso-eugenol 1775, and iso-eugenol 804. In another test two brands of methyl eugenol captured 1827 and 1660 flies respectively, methyl iso-eugenol 721, iso-eugenol 355, oil of citronella (Ceylon) 109, and iso-eugenol (extra) only 72. All the other aromatics were ineffective, attracting less than 2 per cent as many flies as methyl eugenol.

Reaction of the Oriental Fruit Fly to Methyl Eugenol.—Howlett (1915) was unable to determine whether the attractants he tested were of the food, exploratory, or ovipositional type, and he reported that concentrated citronella oil was repellent.

Before the first test in Hawaii was completed it became evident that oriental fruit fly males feed voraciously on pure methyl eugenol. This was substantiated later by exposing the chemical in combination with a dye and observing the rapid appearance of the dye in the abdominal cavity, by determining the loss in weight of methyl eugenol after exposure to flies, and by successfully using methyl eugenol in combination with several different insecticides as poison baits.

The chemical does not attract flies at night when they are normally inactive, but it is effective at dawn and dusk as well as throughout the day.

Flies approaching a methyl eugenol lure in winds above 8 to 10 m.p.h. generally hover close to the ground. At lower velocities their approach is usually direct if the source of the odor is a trap or similar restricted area. Flies have been seen approaching exposed methyl eugenol against 6- to 10-mile winds at estimated speeds of 20 m.p.h.

Strong evidence was obtained that 5 or more milliliter of methyl eugenol exposed on cloth or absorbent paper will attract flies from as much as a half-mile away in 15 or more minutes against winds of 8 m.p.h. or less, from a quarter-mile in 5 or 6 minutes, and from 100 yards in about 2 minutes. The time lag between first exposure and first appearance of flies from downwind was directly proportional to the distance to the nearest fly population when the tests were made in young fly-free pineapple fields. In one experiment some 1300 flies were attracted a half-mile to a muslin screen that had been treated with methyl eugenol and exposed to daylight for 5 hours. None appeared until after 15 minutes had elapsed, but 30 appeared during the next hour and 67 during the first 100 minutes. In a large-scale poison-bait test with parathion and methyl eugenol, the percentage of males in the fly population at distances up to 1 mile from the nearest methyl-eugenol traps became much lower than that recorded anywhere at greater distances.

The area influenced by methyl eugenol is triangular in shape with the base downwind and the width of the base regulated by wind velocity and directional stability. A major change of wind direction often brings on a markedly increased catch.

In olfactometer tests[1] sexually immature males as young as 1 day old showed pronounced preferences for methyl eugenol, as compared with water. Field-collected females, as well as sexually immature laboratory females, also were significantly attracted in the olfactometer, but the numbers of females attracted to methyl eugenol exposed under field condi-

[1] Unpublished studies by Paul Gow and Loren F. Steiner. The olfactometer and the wind-activated trap suspension referred to later are the developments of Paul Gow of the Honolulu Oriental Fruit Fly Investigations' staff.

Table 1.—Comparative performance of oriental fruit fly baits.

Experiment and Bait	Method of Exposure	Number of Days and of Flies per Trap Day		Total Number of Flies[1]
		1st Stage	2nd Stage	
Experiment A:	*Standard traps*	*4 days*	*14 days*	*18 days*
Methyl eugenol 1 ml.	Emulsion	1,785	147	9,200
	Cotton on cork	1,195	436	10,890
Ceylon citronella 1 ml.	Emulsion	400	21	1,890
	Cotton on cork	251	274	4,840
Experiment B:		*18 days*	*4 days*	*22 days*
Methyl eugenol 1 ml.	Dental roll, exposed	325	171	19,590
Ceylon citronella 1 ml.	Dental roll, exposed	171	84	10,200
Java citronella 1 ml.	Dental roll, exposed	12	6	720
Oil of bay 1 ml.	Dental roll, exposed	41	53	2,840
Experiment C:		*4 days*	*2 days*	*6 days*
Methyl eugenol 1 ml.	Dental roll	386	1,020	10,754
Ceylon citronella 1 ml.	Dental roll	102	1,005	7,263
5 ml.	Dental roll	323	1,677	13,929
Experiment D:		*1 day*	*8 days*	*9 days*
Methyl eugenol 1 ml.	Dental roll, screened	3,990	596	26,274
Ceylon citronella 1 ml.	Dental roll, screened	855	678	18,838
5 ml.	Dental roll, screened	1,780	1,019	29,798
Experiment E:		*10 days*	*4 days*	*14 days*
Methyl eugenol 1 ml.	Dental roll	713	77	23,320
	On cotton in open vial	88	—	—
	Same cotton outside	—	352	—
Ceylon citronella 1 ml.	Dental roll, screened	213	74	7,285
5 ml.	Dental roll, screened	406	137	13,820
Experiment F:		*9 days*	*10 days*	*19 days*
Methyl eugenol 1 ml.	Dental roll, caged	592	363	26,895
	Dental roll, exposed	576	174	20,790
Ceylon citronella 1 ml.	Dental roll, caged	327	320	18,470
5 ml.	Dental roll, exposed	526	415	26,650
Experiment G:	*Standard traps*	*13 days*	*13 days*	*26 days*
Methyl eugenol 1 ml.	Dental roll, screened	1,060	778	71,780
Methyl iso-eugenol 1 ml.	Dental roll, screened	296	254	21,455
	Bottle traps			
Methyl eugenol 1 ml.	Emulsion	441	79	20,320
	Dental roll, submerged	475	538	39,530
Ceylon citronella 5 ml.	Dental roll, submerged	327	435	29,740
Experiment H:		*5 days*	*17 days*	*22 days*
Methyl eugenol 1 ml.	Emulsion	393	114	11,220
	Sponge, submerged	328	237	16,995
	Fiberboard, submerged	429	260	19,665
	Fiberboard, re-used	454	327	23,470
Experiment I:	*Plastic traps*	*4 days*	*16 days*	*20 days*
Methyl eugenol 1 ml.	Dental roll, screened	793	1,492	81,127
	Standard traps			
Methyl eugenol 1 ml.	Dental roll, screened	958	1,217	69,900
Methyl iso-eugenol 1 ml.	Dental roll, screened	91	380	19,315
Iso-eugenol 1 ml.	Dental roll, screened	23	22	1,315
Oil of cajeput (USP) 1 ml.	Dental roll, screened	1	2	89
Oil of cajeput (Tech.) 1 ml.	Dental roll, screened	0	0	5

[1] By all replicates for the duration of the experiment.

tions rarely exceeded 1 per cent of the totals; hence a great sex difference in sensitivity is indicated.

As a food, methyl eugenol appears to have no nutritional value. Most flies apparently cannot stop feeding when they have free access to it, and they kill themselves with over indulgence. Flies also

feed on citronella (Ceylon), but this material and its fumes are toxic to the flies, causing their death.

COMPARATIVE FIELD TESTS.—Methyl eugenol and other attractants were compared in the field in standard glass or plastic invaginated traps (Figure 1), in bottle traps, and in other types. The traps were suspended from wind-driven revolving frames, an arrangement which eliminated most of the positional sources of variation but limited the number of treatments to four. Three of these trap suspensions were operated as replicates at locations 140, 1000, and 1600 feet above sea level in each test.

The aromatics were generally applied to folded 6-inch cotton dental rolls suspended from the corks, and the traps were kept filled with water containing a surface-tension reducing agent to facilitate the wetting of trapped flies. In tests with bottle traps the undiluted materials were usually added to dental rolls or other absorbent materials anchored in the bottom of the bottles before they were filled with water containing the surface-tension reducing agent.

When emulsions were used they were poured directly into the trap.

A second series of tests was run in intermediate locations at 400-, 1100-, and 1500-feet elevations. The various types of traps with the different test materials in them were hung 10 to 20 feet apart, usually in guava, and five to eight treatments were rotated through the same number of fixed positions. The positions of the traps were shifted at the time of each examination. Positional differences were well averaged among the test lures as a result of frequent examinations and the usual 2 to 4 weeks' duration of an experiment.

The number of flies in large catches in standard and bottle traps was estimated by washing the wet flies in acetone, draining off the excess liquid, weighing the catch, and then counting a weighed sample of several hundred from the day's catch.

The results of representative tests are given in table 1. Differences of more than 25 per cent between the catches of any two treatments within an experiment are in most instances significant at the 5 per cent level.

Trap capacity was soon recognized as an important factor, under Hawaiian conditions, but one that would not necessarily affect results in areas where heavy catches are not anticipated. On many occasions effective attractants brought in more flies than the traps would hold before they could be emptied. The more effective lures continued to attract flies to the vicinity and this helped competing but less effective baits by narrowing the measurable differences between treatments. When they were emptied twice in one day, four traps on one of the trap suspensions caught as many as 25,000 flies in 24 hours.

A plastic invaginated trap, the standard glass invaginated trap, and an 8-ounce bottle trap captured up to 7300, 6300, and 2600 flies, respectively, in 1 to 2 days without being emptied during the period. However, when catches between examinations exceeded 1000 to 1500 in the invaginated traps and 300 to 500 in the bottle traps, their efficiency in the retention of flies attracted to them diminished.

Except for experiment A, all chemicals were exposed in three one-trap replicates. The duration of the experiments was varied because it became evident that the effective life of some of the attractants was in inverse proportion to the number and rate at which flies were caught. The data expressed as number of flies caught per trap day in the first and second, or final, stages of an experiment show that the attractant most effective when first exposed was not necessarily the best after several days or weeks of exposure.

Emulsions (Expts. A, G, and H) were generally superior to other formulations at first. However they proved to be short-lived in Hawaii where removal of the heavy fly catches takes away much of the absorbed aromatic, and where rains may wash the chemical out of open-topped traps. Where the catches remain low and rainfall is scant, emulsions could well be the best method of exposing the lures.

Experiment B demonstrated the superiority of methyl eugenol to the two citronellas and oil of bay in an area of low fly abundance.

That access of the flies to the attractants would shorten the effective life of methyl eugenol faster than that of citronella was first suspected after Experiment C, in which the flies tore the cotton rolls containing methyl eugenol to shreds but

left the others intact. When wire cloth was placed tightly around the impregnated cotton in Experiment D (dental roll, screened), exhaustion of the methyl eugenol by feeding was not prevented. Later it was found that the flies have to be held nearly an eighth-inch away from the cotton, as in Experiment F, to prevent their feeding.

Experiment E suggested that methyl eugenol aged in glass at least 6 months loses none of its effectiveness. At several locations on Oahu a few drops of methyl eugenol placed on porous lava rocks along roadsides attracted male flies for 10 to 16 weeks. After its application to lava rock the aromatic was partially exposed to the air, sun, heat, and rain, but it was largely out of reach of the flies.

In Experiment E, citronella Ceylon at 5 ml. per trap gave better results than at 1 ml. Because more than 1 ml. of methyl eugenol often filled the traps with flies faster than they could be serviced, concentrations in most tests were limited to this amount.

In Experiment F additional evidence was obtained that access of the flies to dental roll containing 1 ml. of methyl eugenol shortened the effective life of this lure. Access to dental roll containing 5 ml. of citronella Ceylon actually improved the performance of this aromatic, probably because of the disappearance of some of the repellent constituent either through feeding, regurgitation, or increased volatilization. During the first day of exposure loss in weight of citronella Ceylon by volatilization was at least three times as rapid as that of methyl eugenol. Flies having access to citronella were killed very rapidly when it was fresh but less rapidly later on. When they had access to methyl eugenol, fewer than 100 flies reduced 2.5 ml. of this material by 17 per cent in 24 hours. Loss of methyl eugenol by volatilization in the absence of flies was less than 6 per cent. During the latter part of comparative tests, when both materials were exposed to fly feeding, methyl eugenol had about the same effectiveness as five times as much citronella Ceylon.

These studies demonstrated that methyl eugenol should be protected from fly feeding in areas where oriental fruit fly catches may be heavy. The superiority of methyl eugenol to oil of citronella Ceylon was perhaps far greater than it was possible to show in these tests, where full traps often limited performance.

Experiments G and I demonstrated that methyl iso-eugenol is less than one-third as effective as methyl eugenol, and that iso-eugenol and oil of cajeput are of comparatively little value. The performance of iso-eugenol in this experiment and oil of bay in Experiment B was in disagreement with Howlett's (1915) results.

The 8-ounce bottle trap was completely effective, but its catches were smaller than those of the standard invaginated trap (Expt. G), which in turn caught fewer flies than the plastic invaginated trap (Expt. I). These differences occurred almost entirely during periods when the smaller bottle traps were making near capacity catches of male oriental fruit flies. The bottle traps should be entirely satisfactory for scouting purposes on the mainland to detect the presence of limited numbers of flies.

Experiment H demonstrated that a porous material anchored in the bottom of the bottle trap, on which the methyl eugenol was placed before the water was added would increase trap efficiency. When such a trap was re-used after the methyl eugenol was replenished at 2- or 3-week intervals, it was more effective during the subsequent period of operation than when baited only with the original concentration of methyl eugenol.

A trap that would maintain a reasonably constant level of attractiveness over a long period of time was needed for making population studies in small areas. The effectiveness of 2 ml. of methyl eugenol impregnated in a 2-inch length of cotton dental roll inside a 2.5 inch length of 0.375-inch (i. d.) glass tubing, with one end inserted in the cork of the standard invaginated glass trap and the other end open, was only 13 per cent less than that of a freshly prepared similar lure at the end of 3 months. This method of exposure, when compared with the exposure of 1 ml. of methyl eugenol on exposed dental roll, was 85 per cent less effective during the first month but 10 times more effective during the third and 30 times more effective during the fourth month. This method of baiting a trap was too effective for use in the center of plots of less than 1 acre, as it

Table 2.—Males of oriental fruit fly collected in treated and untreated fields.

Month	Average Number of Males per Methyl Eugenol-Parathion Trap	Per Cent of Males in Standard Traps				
		In Treated Field	Miles from Nearest Methyl Eugenol			
			0.2–0.25	0.25–1	16[1]	20[2]
January	0	39	37	36	40	38
February	9,030	21	19	28	32	48
March	5,560	6	15	20	33	43
April	1,320	3	7	19	31	33
May	316	0	5	25	36	24
June	915	18	21	15	56	27
July	5,450	22	37	61	34	37
August	8,880	25	29	60	63	35
September	6,230	22	21	31	39	39
October	3,180	19	28	27	44	32

[1] At Aiea on Leeward Oahu.
[2] At Kaneohe on Windward Oahu.

attracted flies from beyond the plot borders. Ceylon citronella used in a comparable manner caught only 3 to 7 per cent as many flies as methyl eugenol.

In other tests the attractiveness of methyl eugenol was not significantly improved by supplementing it with mineral or vegetable oils, glycerin, triacetin, or oil of cajeput. However, the addition of an equal amount of oil of anise doubled its effectiveness when the mixture was exposed in cotton in the standard glass traps. This was not the case when the impregnated cotton was submerged in bottle traps. Oil of anise alone was unattractive. When catches in the 8-ounce bottle traps containing fibreboard inserts averaged only about 100 flies per day, enough methyl eugenol was retained after 30-days' exposure for 70 per cent efficiency for another 2 weeks, as compared with freshly installed traps.

Methyl eugenol was only slightly effective in inverted ice-cream cartons coated inside with a sticky compound.

EXPERIMENTS WITH POISON BAITS.—Poisoned baits were tested by painting a slurry of a toxicant and an aromatic on the inside surface of 3 by 12 by 16 inch boxes each with one open side. The boxes were suspended from a support and they were covered with 4-mesh hardware cloth on the upper part of the open side and completely closed below to form a receptacle to hold the catch of dead flies. In a test lasting from Nov. 8 to Dec. 1, 1949, two such boxes baited with methyl eugenol or oil of citronella Ceylon caught 27,240 and 6,540 flies, respectively. The traps were given an initial treatment of 2 ml. of the aromatic plus 2 grams of 25 per cent parathion wettable powder. They were retreated 5 times during the period of the test, making a total of 9 ml. of the aromatic for the 6 treatments. No additional parathion was required.

Table 3.—Guava fruit production and mean infestation, summer crop 1950.

Location of Sample Tree	Pounds of Fruit	Number of Larvae in 1 Pound	Per Cent of Larvae Parasitized
Gulch south of treated field	161	31.6	43
Gulch at the southwest end of treated field	175	37.8	68
Gulch adjacent to treated field	545	4.2	50
Gulch at the west end of untreated field	325	39.6	19
Gulch located 0.5 to 2 miles southwest of treatment area	282	32.8	46

First-day catches after the attractant was replenished each time averaged 4 times those of the second day and 10 times those of the third day for each aromatic. A subsequent experiment with methyl eugenol and parathion proved that the loss of effectiveness during the first week was largely the result of consumption of methyl eugenol by the flies. Flies that had consumed methyl eugenol proved to be attractive to other flies; hence, the daily removal of flies caught in these traps was a factor in reducing over-all trap effectiveness.

Four insecticides were compared in an unreplicated test in which the box traps were hung in a cluster facing four directions. The position of the traps was changed once or twice daily. The experiment was started on January 4, 1950 in a back yard avocado tree. Insecticide formulations used in the slurry were 2 grams of 25 per cent parathion wettable powder, 2 ml. each of 24 per cent aldrin and dieldrin emulsions, and 4 ml. of a 25 per cent emulsion of DFDT (2,2-bis-(*p*-fluorophenyl)1,1,1-trichloroethane).

On January 5 a double handful of dead flies was found on top of the boxes and there were at least 35,000 on the ground underneath. During a 15-day period, with the initial 2 ml. of methyl eugenol in each trap being replenished after 10 days, 55,430 dead flies were found inside the boxes and there were many more unaccounted for on the outside. There were no significant differences in the performances of the traps containing the different insecticides. The catches ranged from 13,000

to 15,000 per box trap. In subsequent tests in which traps were lined with fiberboard (canec) to help prevent loss of methyl eugenol by fly feeding, it was indicated that insecticide emulsions may be much less effective than wettable powders when used in this type of trap.

CONTROL OF THE ORIENTAL FRUIT FLY THROUGH REDUCTION OF THE MALE POPULATION.—The first-known field test designed to control an insect by the use of a bait that attracts and kills the males before they are able to fertilize the females, was set up along the borders of a 125-acre pineapple field and the rims of adjacent deep gulches containing many guava trees. The test was started on January 25, 1950. Forty-five box traps were placed around the 4-mile perimeter of the field. They were painted inside with a parathion slurry at intervals of 6 to 8 weeks and treated each week with a spray of 12 cc. of 33 per cent methyl eugenol emulsion. Parathion rapidly paralyzes and kills flies that consume it. As a result, most flies that entered the traps died inside them.

The effect on the male population was measured at weekly intervals with 28 standard glass traps baited with the standard sugar, vinegar, and yeast lure placed around the treated field. An equal number of these traps was operated around an untreated field located 0.2 to 1 mile to the windward (NE) of the nearest methyl eugenol traps. The sex ratios in these traps were also compared with catches in standard traps located 16 and 20 miles from the test field.

In mid-August the concentration of methyl eugenol in the box traps was increased to 12 ml. of 66 per cent emulsion. This amount was subsequently found to be more than that lost from one weekly treatment to the next when total catches were below 50,000 flies.

Pertinent data on fly catches per month are given in table 2. Mean trap catches in the treated field during the 10-month period were 1060 flies of both sexes for the standard traps and fermenting bait, as compared with about 41,000 males for the parathion-methyl eugenol traps. In January, before the experiment started, the sex ratios in the standard glass-trap catches were similar at the various locations. In February slight differences in total catches developed and the male ratio fell off in both fields. Male catches in the treated field dropped to zero for 7 weeks in April, May, and June. It then rose sharply after the ripening of the first guavas in the vicinity. The increase in number of males was concentrated at the extreme downwind end of the treated field and it began before flies could emerge from the new guava crop. Thereafter with new flies arriving as well as being produced locally, it was more difficult to reduce the percentage of males in the catches, probably because of the increase in the proportion of newly emerged, sexually immature males and the normal time lag between emergence and capture.

Although prevailing trade winds were from the untreated to the treated field, the early morning air movement was often in the opposite direction and methyl eugenol odors undoubtedly reached into the untreated field. Traps 0.2 to 0.25 mile away immediately across the gulch caught a lower percentage of males than those 0.25 to 1 mile away. Normal sex ratios occurred in the catches made at Aiea and Kaneohe, 16 and 20 miles south of the experiment.

Releases of newly emerged flies marked on the thorax with colored enamels were made at 2 points in the untreated and 2 in the treated fields on May 11. The first recovery was made 7 days later with methyl eugenol traps, the last 55 days after the flies were released. Sixty per cent of the recoveries occurred within 16 days after release. Two of 230 males released at one point flew south or southwest to traps located 1 to 1.5 miles away in the treated field. Thirteen males from another release moved southward across the gulch into the treated field, traveling minimum distances of 1500 to 4000 feet. Of 175 males released in the treated fields, 22 were recovered at varying distances up to 2500 feet west of the release point. The only flies that moved against prevailing winds were 29 of 40 recoveries from another release of 230 flies that was made on the lee side of a grove of trees. These flies moved through the grove to traps on the windward side. As flies tend to congregate in wooded areas, the most effective locations for traps near such a location would be the windward side.

It was apparent when the releases were made that most of the flies were carried by the strong trade winds and that they

later moved back to traps downwind from the release points. Although an equal number of females were released, only one recovery was made by fermenting lures. This was 1500 feet downwind from the release point.

The results indicate that the strong trade winds may sweep flies for considerable distances.

Five scattered guava trees on the rims or in the gulches were marked for sampling at each of five locations. All ripe fruit was collected weekly from early June to late September 1950, and held for fly emergence. The infestation data in table 3 indicated that a substantial reduction in the infestation in the gulch protected by the box traps along the borders of the adjacent pineapple field may have resulted from the removal of male flies, and that differences in the amount of parasitization were not responsible. The other gulches sampled were all closer to outside sources of fertile females than the gulch immediately north of the treated field. With fly movement as extensive as it is known to be, the full benefits of this possible means of control cannot be fully evaluated until isolated populations are treated or box-trap coverage can be extended over much larger areas than was possible in this experiment. These preliminary results suggest that this inexpensive method has unusual promise.

SUMMARY AND CONCLUSIONS.—Studies of methyl eugenol in Hawaii have demonstrated that the attractiveness of this material to male oriental fruit flies, *Dacus dorsalis* Hendel, ranks as one of the outstanding examples of insect chemotropism. More than 4 million flies were captured within 10 months. As a result of these studies, methyl eugenol was adopted by California authorities for their extensive scouting program initiated in 1950. Tests were also conducted with more than 60 other insect attractants, including citronella Ceylon, and with several types of traps. Most of these were comparatively ineffective. Methyl iso-eugenol, iso-eugenol, and citronella Ceylon were good attractants but much less effective than methyl eugenol.

Male flies fed voraciously on methyl eugenol and greatly reduced the effective life of this bait when it was not protected against their feeding. Methyl eugenol was 10 or more times as attractive as citronella Ceylon, the second best attractant.

Methyl eugenol and citronella emulsions were effective when first exposed but when heavy fly catches soaked up the aromatics or rains caused traps to overflow, the loss of the attractants was accelerated. Methyl eugenol was most effective in open-bottle traps when a porous fiberboard or similar material was anchored at the bottom and impregnated with the attractant before water was added to fill the trap. Under such conditions or in invaginated glass traps in which dental rolls impregnated with the attractant were protected from fly feeding, 1 ml. of methyl eugenol per trap remained highly effective for a month or longer. A few drops placed on porous lava rocks exposed to the weather attracted flies for 10 to 16 weeks.

Strong evidence was obtained that male flies can be attracted 0.5 mile or more against an 8-mile-per-hour wind in 15 or more minutes.

A combination of methyl eugenol and parathion wettable powder made a very effective poison spray or paint for treating the inner surface of box-type traps. Forty-five such traps were used in a test to determine the possibilities for controlling the oriental fruit fly by destroying the males before they are able to fertilize the females. A substantial reduction in the male population in an area of at least 4 square miles was obtained with the use of 4 to 8 ml. of the aromatic per trap per week. Infestation data from guavas showed that the lowest infestation, 4.2 larvae per pound of fruit, occurred in a gulch near the center of the area influenced by the bait, whereas infestations in four surrounding gulches ranged from 31.6 to 39.6 larvae per pound.

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Plum Curculio Control on Peach in 1951[1]

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New organic insecticides for control of the plum curculio *Conotrachelus nenuphar* (Hbst.) have been under investigation at Fort Valley, Ga., during the last 6 years. The results of 5 years' work have been published (Snapp 1947, 1948, 1949, and 1951), and the present paper reports the results of experiments with these insecticides in 1951.

Although the plum curculio infestation in the Fort Valley district was generally lighter than that of an average year, the heaviest infestation in 31 years of orchard experiments developed in one of the orchards used in 1951. Seven rows of scattered peach trees adjoining the experimental plots were inadvertently left unsprayed throughout the season, and these trees may have been partially responsible for the very heavy plum curculio infestation that developed in this orchard.

ORCHARD EXPERIMENTS.—A number of materials were tested as sprays in both small-plot and large-plot orchard experiments. Most of these materials were obtained as commercial preparations, under trade names or code numbers. Unless otherwise indicated, wettable powders were used. Information regarding products for which no official common name has been adopted is given below:

I. EPN—0-ethyl 0-*p*-nitrophenyl benzenethiophosphonate.
II. Compound 1189—A product containing 25 per cent of an oxygenated dimer of hexachlorocyclopentadiene.
III. Metacide—A liquid product containing 30 per cent of a 1:4 mixture of parathion and its methyl homolog.
IV. Malathon (4049)—A commercial product containing 25 per cent of 0,0-dimethyl dithiophosphate of diethyl mercaposuccinate.
V. Potasan—A product containing 4-methylumbelliferone 0,0-diethyl thiophosphate.
VI. CS-728—A product containing 50 per cent of a chlorinated product of 1-*p*-chlorophenyl-1-phenyl-2-nitrobutane.
VII. Compound 269—An experimental mixture containing a stereoisomer of dieldrin—1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-endo-dimethanonaphthalene.
VIII. Compound 711—An experimental mixture containing a stereoisomer of aldrin—1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-endo-dimethanonaphthalene.

Certain of these materials are not yet available to the grower, and this report does not constitute a recommendation for their use.

Applications were made with a conventional hydraulic power sprayer. Certain of the applications were made on different schedules as follows:

Schedule A—Petal fall, shuck off, 2 weeks after shuck off, and 4 weeks prior to harvest.
B—Petal fall, shuck off, 2 weeks after shuck off, 5 weeks prior to harvest, and 3 weeks prior to harvest.
C—Shuck off, 2 weeks after shuck off, 5 weeks prior to harvest, and 3 weeks prior to harvest.
D—Petal fall, shuck off, and 4 weeks prior to harvest.

Wettable sulfur, 6 pounds per 100 gallons, was added to all sprays 2 weeks after shuck off and 4 or 3 weeks prior to harvest for disease control. This fungicide was applied alone 2 weeks after shuck off to the trees that received lead arsenate at other times. A mixture of zinc sulfate (36 per cent), 4 pounds, and hydrated lime, 8 pounds, per 100 gallons, was used with lead arsenate as a safener.

When the fruit was harvested, samples consisted of every fifth, eighth, twelfth or fifteenth peach of the several pickings from each tree of the small-plot experiments, and of every tenth or twentieth peach of the several pickings from four record trees in each replicate of the large-plot experiments. The sample peaches were cut open to determine the percentage infested with the plum curculio.

LARGE-PLOT TESTS.—Parathion (in 2 schedules), TM-I, aldrin, dieldrin, and methoxychlor were compared with lead arsenate in experiments conducted on the regular Elberta variety under commercial peach-orchard conditions. There were four replicates of each treatment in a randomized set-up of plots, each of which contained 36 or 48 trees. The insecticides and schedules used and the results obtained are shown in table 1. All of these treatments were also included in the small-plot tests.

The plum curculio infestation that developed in this orchard was about like

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, Dec. 9–13, 1951.
[2] Julius P. Hollon assisted with all experiments reported in this paper.

Table 1.—Results of orchard experiments with various insecticides on large-scale plots for control of the plum curculio on peaches.

Material (Pounds per 100 Gallons)	Number of Applications	Schedule	Per Cent of Infested Drops April 25–May 4)	Per Cent of Infested Fruit at Harvest
Parathion (15%)				
1½	5	B	3.0	0.2
3	4	A	0	1.7
TM-I (25%) 2	4	A	0.5	0.5
Dieldrin (25%) 2	4	A	0.3	0
Aldrin (25%) 2	4	A	1.7	0.6
Methoxychlor (50%) 2	4	A	1.2	3.3
Lead arsenate 2	3	D	25.1	4.2

that which occurred generally in the Fort Valley district this year.

The first treatment in the table—parathion (15 per cent) at the rate of 1.5 pounds per 100 gallons of spray in 5 applications, the last two 5 and 3 weeks prior to harvest—was one of the schedules recommended in Georgia, South Carolina, and North Carolina in 1951.

SMALL-PLOT TESTS.—Tests were conducted on single-tree plots in the orchard in which the unprecedented plum curculio infestation developed, as revealed by 73.4 per cent of curculio-infested fruit at harvest from trees that received no treatment. Each of 12 treatments and a check were replicated eight times in a randomized set-up on the Sullivan's (early) Elberta variety. The insecticides and schedules used and the results obtained are shown in table 2.

Dieldrin was the only material that

Table 2.—Results of experiments with various insecticides on small plots for control of the plum curculio on peaches.

Material (Pounds or Ounces per 100 Gallons)	Number of Applications	Schedule	Per Cent of Infested Fruit at Harvest
Parathion (15%)	5	B	45.6
1½	4	C	58.0
	4	A	76.3
3	4	A	70.1
TM-III 8 fl. oz.	4	A	67.1
TM-I (25%) 2	4	A	63.4
TM-IV 2	4	A	77.7
Dieldrin (25%) 2	4	A	7.4
Aldrin (25%) 2	4	A	49.4
TM-II 2	4	A	50.1
Methoxychlor (50%) 2	4	A	60.0
Lead arsenate 2	3	D	62.4
Check (untreated)	—	—	73.4

Table 3.—Analyses of insecticide residues on peaches from experimental plots (4 applications unless otherwise indicated).

Material (Pounds or Ounces per 100 Gallons)	Date of Last Application	Residue (Parts per Million)
Small-plot tests, sampled July 2		
	June	*Parathion*[1]
Parathion (15%) 1½	14	0.1 or less
	14 (5 applications)	
	4	
3	4	
TM-IV 2	4	None
TM-III 8 fl. oz.	4	0.1 or less
		EPN[1]
TM-I (25%) 2	4	0.1 or less
		Organic chlorine
Aldrin (25%) 2	5	1.6
Dieldrin (25%) 2	5	2.6
Methoxychlor (50%) 2	5	2.2
TM-II 2	5	1.4
Large-plot tests, sampled July 9		
	June	*Parathion*[1]
Parathion (15%) 1½	18 (5 applications)	Less than 0.1
3	11	
		EPN
TM-I (25%) 2	11	0.3
		Organic chlorine
Aldrin (25%) 2	11	0.6
Dieldrin (25%) 2	11	0.4
Methoxychlor (50%) 2	12	2.5

[1] Analyzed by Averell-Norris method.

gave satisfactory control. Differences among the other treatments were probably not significant. Incidentally, the treatments that ranked first and second in these experiments also had the same rank at harvest in the large-plot tests.

PERSISTENCE OF RESIDUES.—To determine the residues of the new insecticides on peaches at harvest time, analyses were made of samples from the two series of treated field plots. The samples were composite ones taken from all replicates. All analyses were made by Jack E. Fahey, Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine. The results of the analyses from both series of plots are given in table 3.

CAGE TESTS.—Five series of cage tests with plum curculio adults were conducted from March to July in 1951. The method employed was the same as that described in a previous paper (Snapp 1947). Single trees were sprayed with the experimental materials, and after the sprays had dried cylindrical screen cages were placed over branches and the curculios were introduced. The full details of these tests will not be given, but the results obtained with certain materials are summarized as follows:

TM-V was effective against both over-

wintered and new first-generation adults, but its residual value was not very good. CS-728 showed promise against plum curculio adults when used at the rate of 2 pounds per 100 gallons. It had fairly good residual value.

TM-VII was effective against new first-generation adults, killing 100 per cent within 4 days when used at the rate of 4 pounds of 10 per cent wettable powder per 100 gallons. Its residual vlaue, however, was not very good.

TM-VIII was not very effective and TDE was comparatively ineffective against plum curculio adults.

EFFECT OF NEW INSECTICIDES ON PEACH FRUIT, FOLIAGE, AND TREES.—The flavor of fresh ripe peaches was not affected by any of the insecticides used in both series of orchard experiments, and no injury to the fruit, leaves, buds, budwood or any part of peach trees could be discerned from the materials listed in this paper, except lead arsenate. With a safener added, lead arsenate caused the usual amount of foliage injury, and at harvest 16 per cent of the fruit from the small plots and 2 per cent from the large plots showed arsenical injury.

SUMMARY.—In both small-plot and large-plot orchard experiments conducted at Fort Valley, Ga., in 1951, dieldrin in four applications placed first and parathion in five applications placed second among materials tested for plum curculio control. Not a single curculio-infested peach was found on the trees tested with dieldrin in large-scale plots in an orchard where the infestation was lighter than that of an average year. In that orchard, parathion, TM-I and aldrin were effective, and methoxychlor and lead arsenate gave fairly good results. Under an unprecedented infestation, the percentages of curculio-infested peaches at harvest ranged from 45.6 to 77.7 for all the other treatments in one-tree plots, as compared with only 7.4 where dieldrin had been used.

The flavor of fresh ripe peaches was not affected by any of the insecticides, and no injury to the fruit, leaves, buds, budwood or any part of peach trees could be discerned from any of the materials except lead arsenate, which caused the usual amount of foliage injury and injured some of the fruit.

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Field Tests of Insecticides for Control of Japanese Beetle Larvae

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It was shown by Polivka (1947) that DDT one year after treatment was as effective as lead arsenate in controlling the larvae of the Japanese beetle, *Popillia japonica* Newm. Fleming & Hawley (1950) reported that in areas treated with DDT at the rate of 25 pounds of the actual toxicant per acre in 1945 at Blowing Rock, N. C., the grub population remained at a low level through 1948. Again heptachlor was found by Polivka (1950) to give excellent control of the insect three months after application when used at rates as low as one pound of the actual toxicant per acre.

This paper is presented as a progress report of the two field tests mentioned in previous reports (Polivka 1947, 1950) and of three others that have been established at various times since 1945. These additional field tests were set up to obtain more information on the residual effectiveness of the various soil insecticides when used at different application levels.

The organization and arrangement of all tests have been the same except that

Table 1.—The mean grub population by treatments for different years in plots established in Washington Park, Cleveland, October 2, 1945.

Toxicant	Pounds per Acre	Mean Grub Population per Sq. Ft.					
		June 4 1946	May 27 1947	May 11 1948	May 16 1949	Oct. 16 1950	Oct. 12 1951
Lead arsenate	435	1.6	.2	1.0	3.6	21.8	23.0
DDT	12.5	.2	.0	.0	.0	1.8	6.2
DDT	25	.0	.0	.0	.0	.2	.8
DDT	37.5	.2	.0	.0	.0	.0	.0
Untreated		9.4	8.0	14.8	13.0	34.0	22.4
Required for significance at 5% level		1.7	3.5	4.5	4.0	3.5	8.8

the number of treatments has varied. All treatments were replicated five times and randomized within the block. Since the plots, which are 10 by 10 feet, are not separated from each other by strips of untreated areas each test consists of a block 50 feet wide with the length varying according to the number of treatments in the experiment.

The soils on which these experiments are being conducted have been disturbed through grading and filling within the past 20 years; therefore it is impossible to classify them into soil types. However, all of the soils are well drained, high in humus especially in the upper two-inch layer, and have a pH value of 4.3 to 4.9.

Grub population records were obtained in the spring, after most of the larvae were near the surface, or in the fall before movement downward had started. The plots were sampled by taking three eight-inch cores to a depth of eight inches. This amounts to one square foot or 1 per cent of the area in each plot. The cores were placed upon a small portable table especially designed for the purpose and the soil examined for grubs.

The field test established in 1945 in Washington Park in Cleveland consists of one level of lead arsenate, three of DDT, and one of an untreated area. The level of lead arsenate used was 435 pounds per acre and the levels of DDT were 12.5, 25, and 37.5 pounds of the actual toxicant per acre. The required amount of insecticide for each plot was mixed with two pounds of milorganite and broadcasted with a small hand flour sifter. The results of this field test are shown in table 1.

A review of the data in this table shows that the 37.5 pound rate of DDT has given highly significant control of the Japanese beetle larvae for each of the sampling dates. While the 12.5 and 25 pound rates of DDT are still effective, they began to show some decline in effectiveness in 1950 with the 12.5 pound level showing a marked decrease in effectiveness in 1951. Lead arsenate which became ineffective in 1951 began a gradual decline in effectiveness in 1948.

On September 6, 1946, a field test was set up in Forest Hill Park in East Cleveland. This experiment consists of one level each of lead arsenate and DDT, four levels

Table 2.—The mean grub population by treatments for different years in plots established in Forest Hill Park, East Cleveland, September 6, 1946.

Toxicant	Pounds of Actual Toxicant per Acre	Mean Grub Population per Sq. Ft.			
		Oct. 4 1946	May 28 1947	Oct. 30 1950	Oct. 16 1951
Lead arsenate	435	13.8	12.2	.0	.3
DDT	25	16.8	6.4	.0	.0
Chlordane	1	13.2	6.8	.2	6.8
Chlordane	5	6.8	2.2	.0	.0
Chlordane	15	3.8	1.8	.0	.0
Chlordane	25	4.6	2.2	.0	.0
Untreated		18.4	13.0	6.6	20.0
Required for significance at 5% level		11.6	5.9	2.8	12.6

Table 3.—The mean grub population by treatments for different years in plots established in Riverside Cemetery, Cleveland, October 31, 1947.

Pounds of Lead Arsenate per Acre	Mean Grub Population per Sq. Ft.			
	May 4 1948	May 16 1949	May 10 1951	Oct. 19 1951
435	4.4	.0	1.2	2.4
870	3.4	.0	.0	.6
1,305	1.6	.0	.0	.2
Untreated	20.0	13.0	14.8	13.8
Required for significance at 5% level	5.3	2.8	2.3	1.8

of chlordane, and an untreated check. Lead arsenate was used at the rate of 435 pounds per acre, DDT at 25 pounds per acre, and chlordane at levels of 1, 5, 15, and 25 pounds of the actual toxicant per acre. The lead arsenate and DDT were applied as in the previous experiment, while the chlordane was applied as an emulsion.

The data in table 2 show that the 5, 15, and 25 pound chlordane treatments reduced the population significantly in one month after application and continued to remain highly effective through 1951. In May of 1947, all levels of chlordane and the one DDT treatment were found to be significantly different from the untreated plots, while the lead arsenate treatment was not. The records taken in 1950 and 1951 show that all of the treatments were highly effective. However, the 1951 data for the one pound level of chlordane indicate that it had begun to show a somewhat rapid decline in effectiveness.

The field test established on October 31, 1947 in Riverside Cemetery in Cleveland consists of three levels of lead arsenate and an untreated check. The levels of lead arsenate used were 435, 870, and 1305 pounds per acre. The required amount of insecticide for each plot was mixed with two pounds of milorganite and applied with a small fertilizer spreader.

A review of the data in table 3 shows that all levels of lead arsenate have been highly effective in reducing the grub population. However, the data would indicate that at the end of the 1951 season all of the levels were losing some of their effectiveness with the greatest decline occurring in the lower concentrations.

On April 6, 1948, another field test was established in the Youngstown Country Club in Youngstown including one level of lead arsenate, two of DDT, three of chlordane, and untreated check. Lead arsenate was applied at the rate of 435 pounds per acre, DDT at 12.5 and 25 pounds per acre, and chlordane at 5, 20, and 25 pounds of the actual toxicant per acre. The insecticides were applied as in the previous experiment.

A study of the data in table 4 shows that all levels of chlordane and lead arsenate gave highly significant control by October of 1948 and continued to remain effective for the other two sampling dates. The peculiar results obtained with the two levels of DDT cannot be explained since these materials were as effective as lead arsenate and chlordane in 1950 and 1951.

The field test established June 8, 1949 in Springhill Cemetery in Wellsville (Polivka 1950) to compare the effectiveness of various levels of heptachlor in controlling the Japanese beetle larvae was again evaluated in September of 1950 and October of 1951. The results are shown in table 5.

Table 4.—The mean grub population by treatments for different years in plots established at the Youngstown Country Club, Youngstown, April 6, 1948.

Toxicant	Toxicant per Acre	Mean Grub Population per Sq. Ft.		
		Oct. 13 1948	Oct. 23 1950	Oct. 10 1951
Lead arsenate	435	1.0	.2	.0
DDT	12.5	8.0	.0	.0
DDT	25	26.2	.0	.3
Chlordane	5	.0	.0	.0
Chlordane	20	.0	.0	.0
Chlordane	25	.0	.0	.0
Untreated		43.2	11.6	12.8
Required for significance at 5% level		10.4	7.0	12.2

Table 5.—The mean grub population by treatments for different years in plots established in the Springhill Cemetery, Wellsville, June 8, 1949.

Pounds Actual Toxicant per Acre	Mean Grub Population per Sq. Ft.		
	Sept. 19 1949	Sept. 29 1950	Oct. 5 1951
1	.2	2.8	.2
5	.0	.0	.0
10	.0	.0	.0
20	.0	.0	.0
Untreated	18.2	9.0	9.8
Required for significance at 5% level	9.3	8.1	2.0

It may be noted from table 5 that the 5, 10, and 20 pound levels of heptachlor gave excellent control of the Japanese beetle larvae for the three sampling dates. The variation in the results obtained with the one pound level may have been due to the large number of first instar larvae taken in 1950.

SUMMARY.—Lead arsenate applied to soil at the rate of 435 pounds per acre ceased to be effective in controlling the Japanese beetle larvae in the sixth generation after application as shown in the first experiment. In the third field test, when it was applied at the same rate, it shows some decline in effectiveness in the fifth generation while the 870 and 1305 pound rates were highly effective for the same period. The DDT level of 12.5 pounds of the actual toxicant per acre was very effective for 6 generations but in the seventh there was a marked decline in effectiveness while the 25 and 37.5 rates remained effective throughout this period. Chlordane applied at the rate of 1 pound of the actual toxicant per acre gave excellent control of the grubs for five generations while the 5, 20, and 25 pound levels were highly effective for the period under observation. The data obtained from the heptachlor field test indicate that the 5, 10, and 20 pound levels will remain effective for several additional generations of the Japanese beetle.

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A Stink Bug, *Euschistus conspersus*, Destructive to Deciduous Fruits in California

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The economic importance of the consperse stink bug, *Euschistus conspersus* Uhler on deciduous fruits was first recognized in California by Madsen (1950). Although Essig (1926) had previously noted it as a pest of berries, the sudden outbreak of this insect in 1950 and 1951 placed it as one of the major pests of deciduous fruits during these seasons. Most of the damage done by its feeding occurred on Bartlett pears, but apples, apricots, figs, plums, and peaches also suffered heavy damage when interplanted in the infested orchards. Pear orchards in the Sierra foothill counties of California suffered heavy losses in 1950, and damage was even more widespread in 1951.

TAXONOMY.—The consperse stink bug is probably native to California, as it was first described by Uhler in 1897 from specimens collected near San Francisco. His original description lists this pentatomid as suboval, grayish brown on testaceous ground, pale beneath, sprinkled with rufous on the venter; dorsum punctures fine, black, deep, and moderately close together; antennae yellow with apical joint dusky except at base, barely longer than fourth, basal joint short; legs yellow, remotely dotted with black; length 11–12 cm.; width across humeri 6 to 6.5 cm.

Van Duzee (1904) emphasized the following characters: antennae rufous with apical two-thirds of the fifth joint blackish, the second joint distinctly shorter than the third; scutellum convex on the base and narrow toward the apex, extreme tip slenderly edged with white and obviously depressed; legs conspicuously dotted with black (Fig. 1). These latter points serve to distinguish *Euschistus conspersus* from *E. inflatus* Van Duzee, a closely related species. *E. variolarius* P. DeB., which occurs in California, may be distinguished from *E. conspersus* by the absence of a minute black point at each incisure on the margin of the venter.

DISTRIBUTION.—Van Duzee (1904, 1917) gives the distribution as California, Washington, and Vancouver Island. O'Neill (1948) reported it as damaging peaches near Wenatchee, Washington. The collection at the Academy of Sciences, San Francisco, California, has several

FIG. 1.—The consperse stink bug, *Euschistus conspersus* Uhler.

specimens from Oregon, as well as a few from Nevada and Idaho. In California, it has been collected in 39 of the 58 counties and is known to be of economic importance on decidous fruits, especially pear, in six counties: Mendocino, Lake, Placer, El Dorado, Sacramento, and Tuolumne.

LIFE HISTORY IN THE FIELD.—Field studies were undertaken in 1951 by the Division of Entomology and Parasitology, University of California at Berkeley, and are summarized as follows: Adult bugs spend the winter hibernating in the orchards under weeds or trash on the ground. In orchards with cover crops, they prefer the dry, dead grass and weeds under the trees which offers the most protection. The hibernation period began in November in the Sierra foothill orchards, and

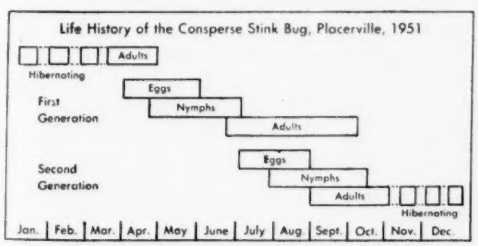

FIG. 2.—Life history of the consperse stink bug in California.

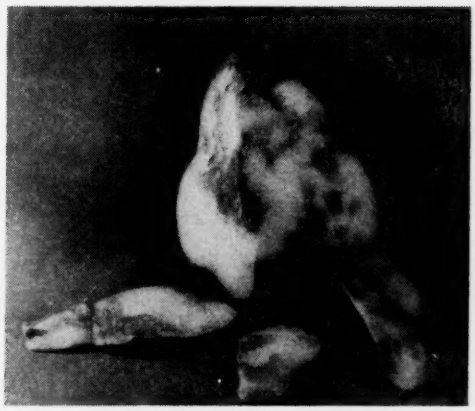

FIG. 3.—Pear fruit showing damage caused by feeding punctures of the consperse stink bug.

ended in the following March. Adults began activity in the early spring, about the first of April, and began feeding on the green broad leafed plants in the cover crop, principally dock and yellow mustard. Egg laying begins shortly after emergence of the hibernating adults, and eggs are laid on the undersides of broad leaf plants such as dock, mustard, horehound, mallow, plantain, and other weeds. At the same time, the bugs migrate to blackberry, mullein, thistle and other green plants outside the orchard and egg laying takes place on these hosts as well. Eggs are also laid on pear leaves, but proportionally few eggs were found on pear leaves as compared with eggs found on green plants inside and outside the orchards. Eggs are laid in groups of 7 to 20 or more per mass. Newly deposited eggs are pearly white in color, barrel-shaped with a ring of spines around the top. As the eggs mature, they turn light pinkish in color. The incubation period of the first generation eggs ranged from 7 to 30 days, since development is dependent upon temperature. Upon hatching, the first instar nymphs remain clustered about the old egg mass from 12 to 48 hours. The nymphs pass through five instars before the adult stage is reached. Nymphs, with the exception of the first instar which apparently does not feed, depend upon succulent broad leaf plants for their food, and cannot develop on pear leaves even though they hatched from eggs laid on pear foliage. This observation was confirmed by means of feeding tests conducted in the laboratory. The nymphal period, from hatching to adult

of the first generation, varied from 67 to 79 days in the field. Adults of the overwintering population fed to some extent developing fruit, but apparently do not cause serious damage at this time. By mid-June, adults of the first generation reached maturity. Adults developing outside the orchards migrated back to the green orchard areas when the host plants began to dry up in midsummer. Adults of this generation feed on the fruit and the cover crop, and it is at this period (just prior to harvest) that the most damage is done to the near mature fruit. First generation adults deposit egg masses on fruit tree foliage, cover crops, and even on dry trash on the ground. Any smooth surface seems to serve as a place for egg deposition, and adults congregate wherever green cover crops are present. At this time of year, these areas are mainly within the orchards and in green home garden plots located near the orchards. Eggs of the second generation hatch in from 5 to 9 days depending upon temperature. Second generation nymphs feed almost entirely on succulent host plants. Only a few fifth instar nymphs were found on the low hanging fruit of pear trees. The nymphal period of the second generation is somewhat shorter than that of the first generation, varying from 40 to 65 days, and a few nymphs were found up to the time the adults are ready to go into hibernation. There is some overlapping of generations during this period of from June through July. By the time second generation bugs reach the adult stage, the pears are harvested, and no damage occurs to the crop from this brood. It is this generation, however, that overwinters in the orchard, and provides a population for the next season. There is a possibility that some first generation adults go into hibernation as well, but this point has not been confirmed. In other areas of the state where summer temperatures are cooler, there is evidence that only one generation is produced, and that adult bugs go into hibernation at earlier periods. In the Sierra foothill orchard, there were two complete generations from early April to November. The first generation developed during April, May and June, and ended in October. The second generation started early in July, and continued on until hibernation in November. No eggs were found in infested orchards after September 1 (Fig. 2).

ECONOMIC IMPORTANCE.—The greatest damage to the pear crop is caused by the feeding of first generation adults. Bugs emerging from hibernation feed on young fruit and may cause some drop, but this damage is not significant. First generation adults feed around the stem end of the near mature pear fruit, and gradually extend the feeding area towards the middle of the pear. The feeding punctures produce white, corky areas under the skin of the fruit which may extend one-half inch into the flesh (Fig. 3). The feeding areas on pears are not usually discernible except for the presence of small black droplets of excrement on the surface, until the skin of the fruit is removed. The white, corky areas turn brown when exposed to the air, and the fruit is unfit for cannery or marketing purposes. Heavy feeding of the adults may produce dimpling or distortion of the mature fruit. On apples, the feeding areas appear as dark green spots under the skin, and on apricots, the flesh turns white and shows through the thin skin of the mature fruit. A single adult bug can cause considerable damage, as it moves from fruit to fruit, and often will damage all the pears in a single cluster.

In some heavily infested areas, the outside two rows of trees have shown as much as 90 per cent damaged fruit, caused by adults migrating in from adjoining weedy areas. The fruit from the inside area of these orchards have shown from 10 to 50 per cent damaged fruit.

Laboratory feeding tests have shown that the consperse stink bug will feed on a wide variety of fruits and vegetables. This establishes the insect as a potential problem on a wide variety of crops. In one area the past season, considerable damage was done to tomatoes by the feeding of this bug.

PARASITES AND PREDATORS.—Eggs of *Euschistus conspersus* are attacked by small hymenopterous parasites. Four species were reared from parasitized egg masses and were determined to be members of the family Scelionidae belonging to the genera *Trissolcus*, *Telenomus* and *Hadronatus*. All four species are probably new, and have not been described. Parasitized eggs turn black in color which is in contrast to the normal white or pinkish eggs. Parasitism of the first generation eggs was very low, and only a few parasitized egg masses were found. Eggs of

the second generation, however, showed a much higher degree of parasitism. The percentage parasitized eggs varied greatly from orchard to orchard in the same general area, one orchard showing 85 per cent and another only 8 per cent. Egg parasites, at least in 1951, were not numerous enough to reduce stink bug populations below economic levels. One predator, a bug belonging to the family Reduviidae was found attacking adult consperse stink bug, but only one example of this predatory action was observed in the field.

CONTROL.—Some preliminary tests of insecticides on the cover crop in early spring and again in late fall were carried out. Ground application of a number of materials were made using a conventional type sprayer with a pump pressure of 350 psi and broom spray guns. Pre-spray counts were made by removing the cover crop from yard square ground areas, and counting adults and nymphs found within this area. The counts showed an average of 17 adults per square yard prior to the spring applications, and 18 adults and 28 nymphs prior to the post-harvest treatments. Materials tested were chlordane, toxaphene, lindane, 12 per cent gamma BHC, parathion, DDT, aldrin, and dieldrin. Of the above materials, used at the following amounts per 100 gallons of spray, lindane at 1 pound, 25 per cent parathion at 1 pound, and dieldrin at 8 ounces actual, gave upwards of 95 per cent control. DDT in early season applications at 4 pounds 50 per cent per 100 gallons showed a high percentage kill, but summer and fall applications did not result in adequate control.

Several growers attempted to control the adults migrating into the orchards with applications of from one to as many as five parathion sprays. Although these sprays undoubtedly reduced damage to the fruit, the residual value of the toxicant under high summer temperatures was far too short to be effective.

Chemical control without a program of host eradication is apparently hopeless. Clean culture within the orchard, especially during the time eggs are hatching and host plant eradication in adjoining weedy areas throughout the fruit season is probably the most practical means of control. The reduction of the adult populations by ground applications of insecticides in early spring as the bugs come out of hibernation, and again as a postharvest spray before the adults go into hibernation should aid in reducing the populations.

SUMMARY.—The stink bug *Euschistus conspersus* Uhler, has been a pest of economic importance in a number of deciduous fruit orchards in central California the past two seasons. Life history studies showed that the bug has two complete generations and its development is closely tied to the presence of broad leaf host plants in orchards and in adjoining areas. Bartlett pears were severely damaged by the feeding of the insect especially in the Sierra foothill counties. Feeding of the adult bugs causes white, corky spots under the skin of the fruit, making it unfit for marketing. Control measures suggested are a combination of host plant eradication and chemical control of the bug.

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Control of Onion Thrips in Texas

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Onion thrips, *Thrips tabaci* Linn., are considered a limiting factor in the production of profitable yields of high quality onions. In the Rio Grande Valley of Texas the onion thrips usually migrate from onion plants at harvest time and can be found in destructive numbers on seedling cotton, young tomatoes, small beans, cucurbits and nearly mature potatoes. Onion growers in South Texas usually apply treatment applications only when injurious infestations have developed. As a result, an insecticide which will reach its maximum effectiveness in a 24 hour period as well as one having residual properties is required for effective control.

Good control of onion thrips was obtained with a 5 per cent DDT dust by the following: Chapman *et al.* (1945); Lange (1946); Borden (1946); Hibbs & Ewart (1946); Hoerner & Edmundson (1947); Ashdown & Watkins (1948); Elmore (1949); and Wilcox *et al.* (1949). Wene (1948) showed that a mixture of 0.5-per cent gamma benzene hexachloride and 2.5-per cent DDT was more effective than 5-per cent DDT and as effective as 1-per cent parathion. This benzene hexachloride-DDT mixture was more effective than either 5-per cent chlordane or 10-per cent toxaphene. Fife *et al.* (1948) working on the control of onion thrips infesting cotton found that 5-per cent toxaphene was more effective than the same concentration of DDT. Wene & Mayeux (1949) obtained good control of onion thrips with 20-per cent toxaphene, 3-per cent gamma benzene hexachloride, and a mixture of 5-per cent chlordane with 5-per cent DDT. Wilcox & Howland (1950) showed that parathion, aldrin, chlordane and toxaphene were superior to DDT when used as dusts. Using low volume sprays Mayeux & Wene (1950) found that a mixture of benzene hexachloride and DDT was superior to benzene hexachloride or DDT used alone. Sloan & Rawlins (1951) showed that 5-per cent heptachlor was more effective than the same concentrations of aldrin and dieldrin. However, they found that 5-per cent dust concentrations of aldrin and dieldrin were almost equal in controlling onion thrips. The data of Hibbs (1946) and Wene (1948) showed that the use of sulphur as a diluent increased the effectiveness of DDT dusts. Mayeux & Wene (1951) found that the largest increase in onion yields was obtained when the thrips control program was started at a low population level.

PROCEDURE.—The experiments were conducted on plots approximately 0.02 acre in size with each treatment being replicated 3 or 4 times. The treatments, except those shown in tables 3, 4 and 8, were only applied once. The treatments shown in tables 3 and 4 were applied 4 times at 10-day intervals whereas those treatments shown in table 8 were applied twice with a 10-day interval between applications. The first experiment was conducted on cabbage whereas the remaining experiments were conducted on onions in the Weslaco and the Winter Haven areas.

The dusts were applied with rotary hand dusters at approximately 18 pounds. per acre. A 3-gallon garden sprayer was used in applying the sprays at the rate of 50 and 100 gallons per acre.

The effectiveness of the various treatments was determined by counting the onion thrips populations at various intervals after treatment. In the control of thrips on cabbage 10 leaves were pulled at random from the center row of each plot and the number of thrips were counted on a 4 square inch area usually in the center of the leaf. In the remaining experiments which were on onions, 10 plants were selected at random from the middle rows of each plot and the average thrips population per plant determined. In those experiments having more than one application the data show the average number of thrips per plant at definite time intervals after each application.

1946 Experiment.—The thrips infestation in this experiment was on half grown cabbage. The data in table 1 show that the action of DDT dust is slower and less than that of benzene hexachloride, which gave maximum control within 24 hours after treatment. The data in the

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Table 1.—The effectiveness of gamma benzene hexachloride and DDT dust mixture in controlling onion thrips infesting cabbage. Weslaco, 1946.

Treatments	Average Number Thrips per 4 Sq. In. Area of Cabbage Leaf					
	Days After Application					
	1		2		3	
	No. Thrips	% Red.	No. Thrips	% Red.	No. Thrips	% Red.
0.25% gBHC +2.5% DDT	0.1	99	0.1	99	0.7	91
0.5% gBHC +2.5% DDT	0.1	99	0.0	100	0.1	99
1.0% gBHC +2.5% DDT	0.1	99	0.0	100	0.0	100
0.25% gBHC	0.7	97	0.1	99	2.1	82
0.5% gBHC	0.1	99	0.1	99	0.5	96
2.5% DDT	3.3	84	6.8	62	2.1	82
5.0% DDT	2.2	89	3.3	81	0.7	91
Untreated	20.6	—	17.6	—	14.2	—

table also show that combining 0.5-per cent gamma benzene hexachloride with 2.5-per cent DDT resulted in a mixture that had a quick killing power and good residual effectiveness.

1948 Experiment.—The data in table 2 show that a dust containing 5-per cent DDT and 50-per cent sulphur gave good control of onion thrips. One-per cent parathion dust was more effective than the DDT dust whereas the 0.25-per cent concentration of parathion was less effective. Dust concentrations containing 5- and 10-per cent toxaphene were not as effective as the DDT dust.

1950 Experiment.—The first experiment, shown in table 3, was dusted 4 times at 10 day intervals. Population records were taken 1 and 7 or 8 days after each application, and the average population determined. The benzene hexachloride-DDT dust mixture was considered the standard for evaluating other materials. Population counts taken 7 or 8 days after treatment applications show that 5-per cent heptachlor, 20-per cent toxaphene, 2.5-per cent dieldrin and 2.5-per

Table 2.—Onion thrips populations per plant in plots treated with various dust formulations. Winter Haven, 1948.

Treatments	Days After Application			
	4		8	
	No. Thrips	% Red.	No. Thrips	% Red.
5% DDT+50% Sulphur	0.5	93	2.2	74
1% Parathion	0.8	89	1.4	83
0.25% Parathion	2.0	73	3.9	52
5% Toxaphene+50% Sulphur	1.3	82	3.2	61
10% Toxaphene+50% Sulphur	2.0	73	4.0	52
Untreated	7.2	—	8.2	—

Table 3.—Onion thrips populations per plant in plots treated with various dust formulations. Summary of four applications applied at 10 day intervals. Weslaco, 1950.

Treatments	Days After Applications			
	1		7–8	
	No. Thrips	% Red.	No. Thrips	% Red.
1% Dieldrin	2.3	89	6.8	71
2.5% Dieldrin	1.0	95	5.2	78
2.5% Aldrin	0.5	98	5.5	77
5% Heptachlor	0.4	98	2.4	90
20% Toxaphene	2.6	88	5.0	79
1% Parathion	1.0	95	7.8	67
3% Lindane	2.4	89	12.5	47
3% gBHC	2.8	87	12.7	46
1% gBHC+5% DDT	1.4	94	6.1	74
Untreated	21.6	—	23.5	—

cent aldrin as dusts were more effective than the benzene hexachloride-DDT mixture. Parathion, at a 1-per cent concentration, was more effective immediately after application than the benzene hexachloride-DDT mixture but did not have the residual effectiveness of the latter. Three per cent concentrations of lindane and gamma benzene hexachloride were about equal in effectiveness, but did not have the residual effectiveness of the benzene hexachloride-DDT mixture. One-per cent dieldrin was not as effective as the 2.5-per cent concentration.

At Weslaco 3-per cent of CP-5 sticker was added to various dust mixtures. These dusts were applied 4 times at 10 day intervals. Population records were taken 1 and 7 to 9 days after treatment applications. Data in table 4 show that the sticker used[1] was more effective with the DDT dust, which has a long residual effect, than with a volatile material such as benzene hexachloride. It is interesting to note that the addition of CP-5 sticker

[1] CP-5.

Table 4.—The effect of CP-5 sticker on the toxicity of dusts to onion thrips. Summary of four applications applied at 10 day intervals. Weslaco, 1950.

Treatments	% CP-5[1] Sticker	Days After Applications			
		1		7–9	
		No. Thrips	% Red.	No. Thrips	% Red.
0.5% gBHC	—	10.1	67	42.0	24
0.5% gBHC	3	6.6	78	33.2	40
1% gBHC	—	7.0	77	32.4	41
1% gBHC	3	6.5	79	29.3	47
0.6% gBHC+5% DDT	—	10.9	64	25.7	53
0.6% gBHC+5% DDT	3	8.2	73	25.1	54
5% DDT	—	14.4	53	37.0	33
5% DDT	3	13.6	55	23.0	58
Untreated	—	30.3	—	54.9	—

[1] Manufactured by the Colloidal Products Corporation.

Table 5.—The effect of stickers on the toxicity of insecticides to onion thrips. Winter Haven, 1950.

Treatments	Amount Sticker	Days After Application: 3 — No. Thrips	3 — % Red.	7 — No. Thrips	7 — % Red.
Dust: 1% γBHC+5% DDT+50% Sulphur	———	8.8	76	40.3	52
Dust: 1% γBHC+5% DDT+50% Sulphur	5% CP-5[1]	1.7	95	16.8	80
Spray: 0.25 lb. DDT per 100 gallons water	———	14.4	61	43.5	48
Spray: 0.25 lb. DDT per 100 gallons water	0.25 lb. Z-1[1]	13.2	64	36.0	57
Spray: 0.25 lb. DDT per 100 gallons water	2 oz. Dupont Sticker	24.5	33	50.1	40
Spray: 0.25 lb. DDT per 100 gallons water	4 oz. Triton B-1956	13.5	63	53.1	37
Untreated	———	36.8	—	84.0	—

[1] Manufactured by the Colloidal Products Corporation.

was more effective on the 0.5-per cent concentration of gamma benzene hexachloride than on the 1-per cent gamma benzene hexachloride dust. The data in table 4 also show that mixtures containing benzene hexachloride and DDT were more effective than either benzene hexachloride or DDT used alone in dusts. The 3-per cent sticker did not increase the effectiveness of the benzene hexachloride-DDT mixture. At Winter Haven, stickers were used in both sprays and dusts. The data in table 5 show that a 5-per cent addition of the sticker greatly increased the effectiveness of the benzene hexachloride-DDT. This, with the data in table 4, indicates that stickers such as the one used did increase the efficiency of dusts used for onion thrip control.

Stickers and spreaders were added to high volume DDT sprays used in controlling onion thrips. The data are shown in table 5. One sticker[2] increased the effectiveness of the DDT spray but two others[3] decreased the effectiveness of the DDT spray.

The data in table 6 show that the addition of sulphur greatly increased the effectiveness of toxaphene but only slightly increased the effectiveness of the benzene hexachloride-DDT dust. Addition of sulphur decreased the effectiveness of the 5-per cent chlordane plus 5-per cent DDT dust.

1951 Experiments.—Of all the materials tested as dusts in Winter Haven 3-per cent and 1-per cent gamma benzene hexachloride with 5 per cent chlordane were superior to the mixture of 1-per cent gamma benzene hexachloride with 5-per cent DDT. The data in table 7 also show that sulphur increased the efficiency of DDT in controlling onion thrips. Addition of 5-per cent chlordane also increased the effectiveness of a 1-per cent gamma benzene hexachloride dust. A 1-per cent

[2] Z-1.
[3] Dupont Sticker and B-1956.

Table 6.—The effect of sulphur as a diluent in insecticides used for the control of onion thrips. Winter Haven, 1950.

Treatments	Days After Application: 2 — No. Thrips	2 — % Red.	10 — No. Thrips	10 — % Red.	18 — No. Thrips	18 — % Red.
1% BHC+5% DDT, inert	0.7	63	1.8	67	2.2	48
1% BHC+DDT+50% Sulphur	0.1	93	0.6	89	2.0	53
5% chlordane+5% DDT, inert	0.2	89	0.5	92	1.7	59
5% chlordane+5% DDT+50% Sulphur	0.2	90	1.0	81	2.1	51
10% Toxaphene, inert	0.6	69	1.8	66	2.7	37
10% Toxaphene+50% Sulphur	0.4	80	0.9	83	1.8	58
Untreated	1.8	—	5.4	—	4.2	—

Table 7.—Onion thrips populations per plant in plots treated with various insecticidal dusts. Winter Haven, 1951.

Treatments	Days After Application			
	2		8	
	No. Thrips	% Red.	No. Thrips	% Red.
5% DDT	7.0	70	60.4	27
5% DDT+50% sulphur	4.1	83	27.2	67
5% Chlordane	2.0	91	45.0	45
5% Chlordane+5% DDT	3.1	86	34.3	58
5% Chlordane+5% DDT +50% sulphur	1.5	94	31.4	62
2.5% Chlordane+2.5% DDT	2.1	91	36.5	56
1% γBHC+5% Chlordane	1.8	93	12.1	86
1% γBHC+50% sulphur	3.0	87	22.0	73
1% γBHC+5% DDT+50% sulphur	2.1	91	16.4	80
3% γBHC	1.6	93	10.1	88
1% Parathion	3.2	86	50.5	39
Untreated	23.3	—	82.2	—

Table 8.—Onion thrips populations per plant in plots dusted twice at a 10 day interval with various organic phosphates. Weslaco, 1951.

Treatments	Days After Application			
	1		7	
	No. Thrips	% Red.	No. Thrips	% Red.
1% Parathion[1]	0.9	81	2.7	78
1.5% Metacide[1]	0.8	83	3.3	73
1% EPN 300[2]	1.0	79	4.6	62
1% EPN 300+95% sulphur[2]	0.7	85	3.5	71
2% EPN 300[2]	0.6	87	3.1	74
2% Potasan[3]	1.2	74	8.0	33
1% γBHC+DDT	0.4	91	2.2	82
Untreated	4.7	—	12.0	—

[1] A Mixture of 0,0-diethyl 0-p-nitrophenyl thiophosphate and dimethyl analog If 0,0-diethyl 0-p-nitrophenyl thiophosphate.
[2] Ethyl p-nitrophenyl thionobenzenephosphonate.
[3] Diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin.

Table 9.—Onion thrips per plant in plots treated with various spray formulations. Winter Haven, 1951.

Amount Insecticide per 50 Gallons Water	Days After Application			
	4		8	
	No. Thrips	% Red.	No. Thrips	% Red.
0.125 lb. Dieldrin	6.4	43	35.3	29
0.25 lb. Dieldrin	2.7	77	13.4	73
0.25 lb. Aldrin	2.9	76	20.3	60
0.5 lb. Aldrin	3.4	71	16.5	67
0.15 lb. EPN 300	3.5	71	25.7	49
0.1 lb. Parathion	4.2	65	27.1	46
1.0 lb. Toxaphene	3.0	75	15.8	69
0.67 lb. Toxaphene+0.33 lb. DDT	1.4	88	17.5	65
0.5 lb. Heptachlor	0.6	95	5.6	89
Untreated	11.9	—	50.2	—

parathion dust did not show any residual effectiveness. Combinations of DDT and chlordane were not as effective as the benzene hexachloride-DDT dust in controlling onion thrips.

In table 8 the comparative effectiveness of the organic phosphate dusts as controls for onion thrips is shown. The data show that parathion was superior to three other materials used.[4] However, the mixture of 1-per cent gamma benzene hexachloride with 5-per cent DDT was superior to parathion.

The data in table 9 show that 0.5 lb. of heptachlor per acre was most effective for controlling onion thrips when applied as high volume spray. Toxaphene at 1 pound per acre gave good commercial control. Dieldrin at 0.25 lb. per acre also gave good control. The data also show that in order to obtain good thrips control with aldrin the dosage should be about 0.5 lb. per acre. Parathion and EPN 300 used at the rates shown in the table were inferior to 1 lb. toxaphene in controlling onion thrips. The mixture of 0.67 lb. toxaphene with 0.33 lb. DDT was about as effective as 1 pound of toxaphene.

SUMMARY.—A dust mixture of 0.5-per cent gamma benzene hexachloride with 5-per cent DDT was more effective than either 0.5-per cent gamma benzene hexachloride or 5-per cent DDT. The following dusts, 5-per cent heptachlor, 2.5-per cent dieldrin, 20-per cent toxaphene, and 2.5-per cent aldrin were more effective than a mixture of 1-per cent gamma benzene hexachloride with 5-per cent DDT in controlling onion thrips. Three-per cent gamma benzene hexachloride, 3-per cent lindane, 1-per cent parathion, 1-per cent EPN 300, 1.5-per cent metacide, 2-per cent potasan and 5-per cent chlordane were less effective than the benzene hexachloride-DDT mixture in controlling onion thrips.

Using high volume sprays, 0.5 lb. heptachlor, 0.5 lb. aldrin, 0.25 lb. dieldrin 1 lb. toxaphene and a mixture of 0.67 lb. toxaphene with 0.33 lb. DDT, all gave effective thrips control.

Additions of sulphur and sticker[1] improved the effectiveness of dusts used in controlling onion thrips in some instances and gave contradictory results in others. More work needs to be done before definite conclusions can be drawn.

[4] Metacide, EPN-300 and potasan.

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Determining Emergence of the Cherry Fruit Fly with Ammonium Carbonate Bait Traps[1]

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For successful control of the cherry fruit fly, *Rhagoletis cingulata* (Loew), the date of earliest emergence of the adult must be definitely known. Seven days is the accepted minimum gestation period after emergence from the soil. Failure to detect the date of earliest emergence within a few days usually results in wormy cherries.

In April, 1949, when the writer began a study of the cherry fruit fly in the Yakima Valley, pear psylla sticky boards (Davis 1943; Kaloostian & Yeomans 1944) were used to determine the earliest spring emergence. These consisted of 6 by 10 inches plywood, painted yellow, covered with a sticky material,[2] and hung in the trees. Only those flies which accidentally alighted on the boards were caught.

Reliance upon concentrators, *i.e.*, cages placed in orchards over large numbers of pupae buried in the soil, is not practicable under central Washington conditions. Due to climatic differences in the Yakima Valley, there may be a differential of 1 week between times of emergence within 50 miles. Other cherry districts at While Salmon, Walla Walla, Clarkston, and Spokane have a wide range of emergence dates, and a prohibitive number of concentrators would be required. Thus a simple trap that could be easily made and serviced in quantity was indicated.

Following the lead of Hodson (1948) who observed that baits emitting the odor of ammonia are attractive to the apple maggot, *Rhagoletis pomonella* (Walsh), bait traps containing ammonium carbonate were put on trial in 1949. The tub-shaped carton used by Hodson could not be obtained, but a quart cylindrical waxed frozen food carton[3] proved satisfactory and was very easily and quickly constructed.

The traps are constructed by punching small holes in the bottom from the inside of the carton with a template utilizing 35 nails about 1 mm. in diameter. Driving the nails from the inside of the carton

[1] Scientific Paper No. 1007. Washington Agricultural Experiment Stations, Institute of Agricultural Sciences, The State College of Washington, Pullman.
[2] *Deadline*, a tree-banding material, California Spray-Chemical Corporation, had proven to be the most satisfactory.
[3] *Seabright.*

leaves raised jagged edges around each hole which helps prevent the powdery attractant from sifting through the holes. The inside surfaces of the cartons, but not the bottoms, are thinly covered with sticky material.[1] About 7 grams of the attractant, powdered ammonium carbonate, are poured into the lid which is then fitted over the bottom. A loop of string is fastened to the carton and the traps are hung, open end down, in the trees. They should be inspected each week and ammonium carbonate added as needed.

Tests comparing baited and unbaited quart cartons have shown that the odor of ammonia is definitely attractive to the flies. On June 3, 1949, two unbaited cartons were hung in cherry trees for comparison with five baited traps. During the period from June 3 to July 3, the two unbaited traps collected an average of 15 flies each while the five baited traps each averaged 719 flies. The baited traps are, therefore, 47 to 50 times as effective in catching flies as the unbaited traps.

At Cherry Hill, Washington, a baited trap had 162 flies in it on June 15, 1949, while at the same time a sticky board in the same tree had only 6 flies and another board in a nearby tree had 18 flies. In 1950, results of tests conducted at Prosser (Fye, unpublished data[2]) show that baited quart cartons catch about 48 times as many flies as do the sticky boards.

The behavior of flies in the vicinity of the bait traps has been observed on calm, hot days. The flies within 3 feet of a trap appear agitated and excited. They walk around more rapidly than usual, fluttering their wings, and making short, curving, rapid flights generally towards the trap. Many flies alight on the carton and rapidly run over it apparently trying to locate the source of the odor. Not infrequently they are caught by the sticky material at the lower edge of the carton. Others remain quietly on the cartons for long periods. Many, especially those approaching the traps from below, are caught as they enter the carton while making short curving, flights.

The value of the ammonium carbonate bait trap in determining the spring emergence date becomes apparent by comparing the date of earliest bait trap catch with the dates flies appear in soil cages. In 1949, the first adult was caught in a bait trap on May 19 at Prosser. In the same orchard, heavily infested the previous year, 12 cages 2 feet by 2 feet were placed in promising locations under seven cherry trees. Flies appeared in the first cage on May 22, 3 days after flies had been caught in bait traps. Flies first appeared in eight cages the first week following May 19, in three the second week, and in one 19 days later.

In 1950, 60 cages, 2 feet by 2 feet, were placed at random under 8 trees in the same orchard. The first adult was caught in a bait trap on May 21. Again, 3 days following the earliest bait trap catch, the first fly appeared in a soil cage. Flies first appeared in only three cages the first week following May 21, in 25 the second week, in 19 the third, 10 the fourth, and in 3 the fifth week.

These data clearly show that cages placed over pupae-infested soil are of questionable value in determining the date of earliest emergence.

It is entirely probable that the first fly caught in a bait trap may be 1 or 2 days later than the actual earliest emergence, due to the small number of flies in the trees at that period. Therefore, control programs are initiated in each district with the finding of the first fly in a trap in that district. By the use of the ammonium carbonate bait trap, each district is independent of all the others and each can easily and with reasonable accuracy determine the beginning of its own control period.

[1] *Deadline* is superior to other materials because it remains sticky for long periods.

[2] Fye, Robert E. Biology of the Cherry Fruit Fly. Master's thesis on file at the State College of Washington library, Pullman, Washington.

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Radioactive Materials in Entomological Research[1]

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The purpose of this paper is to bring before entomologists the possibilities of the use of radioactive materials in entomological research, the nature of the problems involved, results obtained in connection with recent research, and to offer suggestions on how to initiate studies in this field. It is firmly believed that radioactive isotopes will assist entomologists in their studies on the biology and control of insect pests affecting plants, animals, and man. Useful information also can be obtained on beneficial insects, such as bees and parasites and predators of insect pests.

GENERAL STATEMENTS ON RADIOACTIVITY.—High-energy radiation comes from the nucleus of the radioactive atom. This energy has been stated to be the same as atomic energy, or radioactivity, as it relates to studies in biology and medicine. It is of course not visible and has no taste, odor, or other properties whereby man or animals can detect its presence. Means of detecting and measuring the intensity of radioactivity are available and will be discussed later in this report. The radiations are of several types, but the following types are most frequently encountered in biological and medical research (U. S. Atomic Energy Commission 1949):

1. Alpha particles—large, highly damaging, positively charged particles. They are unable to penetrate unbroken skin, but if an element liberating them is deposited within the body they may cause severe damage.
2. Beta particles—moderately damaging, moderately penetrating, negatively charged particles. They will go through about 0.33 inch of tissue.
3. Gamma rays—highly penetrating. They are less damaging, quantity for quantity, than either alpha or beta radiations.
4. X-rays—similar to gamma rays but less penetrating.

During the last few years there has been a tremendous interest in development of atomic energy. Man has greatly increased the number of isotopes available. Much radium has been extracted, x-ray machines of great voltage capacity have been designed, and nuclear reactors built. With the building of the atomic bomb, atomic energy has been shaped into one of the most powerful and devastating forces on earth. The tremendous strides made in studies of atomic energy for military purposes have also provided information, equipment, and an impetus for research that have enormous potentialities for the good of mankind. Radioactive materials for physical, biological, and medical studies are now available at reasonable cost.

Radioactive isotopes are used in studies of the breakdown of metals and alloys, the tracing of metabolic processes of plant, animal, and human life, and the diagnosis and treatment of disease. Science, medicine, industry, and agriculture are using these isotopes in thousands of ways to further knowledge of life processes. According to the Atomic Energy Commission, over 6000 shipments of isotopes were made to 305 institutions during 1950.

A few of the more common terms used in biological and medical research are as follows:

1. Isotope—one of two or more atoms whose nuclei have the same number of protons but different numbers of neutrons. Since the number of protons in the nucleus controls the number of electrons in the outer orbits, which in turn controls the chemical nature, all the isotopes of a given element will behave the same chemically. However, because of the different number of neutrons there will be different isotopes. There may be several isotopes of the same element, either stable or radioactive.
2. Curie—the unit of radioactivity designating the number of particles emitted per second by 1 gram of pure radium, or 3.7×10^{10} particles or disintegrations per second.
   Millicurie—1/1000 curie. Microcurie—1/1,000,000 curie.
3. Specific activity—the number of disintegrations per unit time per gram of the radioelement. Usually

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the shorter the half-life of an emitter, the greater is its specific activity.

4. Cpm (counts per minute)—Number of terminal discharges per minute produced by an ionizing event in a Geiger-Mueller tube. The term is used in relation to the number of counts obtained per minute of radioactive samples. It does not necessarily measure the absolute disintegration of the element but is usually the recorded value on a given instrument under given conditions.
5. Half-life—the time required for the disintegration rate of a radioactive isotope to decrease to one-half of its initial value.
6. Background—the activity caused by cosmic rays or radioactive materials nearby or by slight contamination of equipment. Backgound counts must be subtracted from counts obtained from specimens.
7. Roentgen—a measure of the ionizing effect of radiation, an effect that is injurious to living things.

Persons interested in this subject will find it of value to study such texts as *Nuclear Radiation Physics*, by Lapp & Andrews, and *Radioactive Tracers in Biology*, by Kamen. Many other texts dealing with radioactivity are available.

USES OF RADIOISOTOPES.—Radioactive isotopes can be used as tracers in biological and medical research, because before they disintegrate radioactive atoms enter into exactly the same chemical reactions as do the corresponding stable atoms of the same element. Once a radioactive atom has become a part of a molecule, the location of that "tagged" molecule can be determined by Geiger-Mueller equipment or radioautographs.

The tracing method is utilized in the localization and study of the distribution of various elements in plants and animals. The procedure consists essentially in the exposure of the organism to a labeled chemical and the determination, at intervals, of the radioactivity of the intact animal or plant, or parts thereof. Radioactive tracing is an extremely sensitive analytical method primarily because of the extraordinary sensitivity of the devices that have been developed for the detection and measurement of nuclear radiations (Lapp & Andrews 1949).

The use of radioisotopes will be discussed in this paper under the broad headings of (1) toxicological and physiological research, (2) ecology, and (3) other applications. Jenkins & Hassett (1950) has reviewed the literature on uses of radioisotopes in entomology. This is an excellent review of published information and only a few of the references mentioned in their paper will be referred to here.

Toxicological and Physiological Research.—There are several promising uses of radioisotopes in toxicological investigations. The amounts of insecticides in different solvents and in different dosages that penetrate the insect cuticle can be studied. Distribution of the toxicant or its metabolites in the various organs and tissues can be accurately traced. By careful experimentation the amount eliminated by the respiratory and alimentary systems can be measured. It is possible to determine how long absorption continues in insects surviving sublethal dosages, and to study the individual differences in groups of insects by actual measurement of the amount absorbed by each specimen.

Radioactive synergists or activators should be of considerable value in studies of their mode of action when used with insecticides. Studies to determine the distribution of synergists in the various tissues would no doubt assist in explaining how these materials act, either in combination with insecticides or when used separately, in time and space on insects.

Basic research in insect physiology will make greater use of radioisotopes in studies on the life processes of arthropods. Hassett and Jenkins (1951) found that radioactive phosphorus (P^{32}) enters mosquito larvae through the gut, from ingested food, through the anal gills and perhaps through the integument. Its distribution is general throughout the organism, with somewhat heavier concentrations in the Malphigian tubes and in parts where metabolic processes are occurring rapidly. Craig and Olsen (1951) studied the rate of circulation of the body fluid of *Tenebrio molitor* L., *Anasa tristis* (DeG.), and *Murgantia histrionica* (Hahn) by injecting radiophosphorus into the insect. Uniform mixing of the injected solution occurred in 33 minutes or less in the various species of insects.

Studies by Hoffman (unpublished) with house fly larvae reared in a medium con-

taining 2 microcuries of radioactive phosphoric acid per gram, showed that on an average 18 per cent of the total radioactivity in a pupa remained in the empty puparium after the fly emerged, and from 7 to 41 per cent was excreted every 2 days over an 8-day period. Other flies, which were fed a sugar solution containing the phosphoric acid, showed a similar amount of excretion over a 15-day period.

It is also possible that insects can be used in the production of complex radioactive compounds by biosynthesis. Zamecnik, Loftfield, Stephenson, and Williams (1949) injected C^{14}-labeled glycine and alanine into the body cavity of the giant silkworm, *Platysamia cercropia*, and found that thin pieces of cocoon fabric produced by the silkworm exhibited radioactivity under a Geiger-Mueller counter. Chemical tests showed that the radioactivity present was in the alpha-carboxyl group of some amino acid associated with the silk fibers.

As an example of the usefulness of radioactive insecticides in absorption studies, it has been found that absorption or penetration of radioactive DDT continues after the treated insects have died. Treated house flies stored in pill boxes for several months absorbed much larger amounts of the DDT than they absorbed in the first 24 hours after treatment (Hoffman *et al.* 1951-b). The radioassay method showed 1 to 2.5 μgm (microgram) absorbed per fly 24 hours after treatment as compared with 6.5 to 7.5 μgm per fly after about one year. Of this amount 53 per cent was in the internal organs of the flies. Other studies showed increased absorption in dead flies 2 to 10 days after treatment over that obtained in 24 hours. It is obvious that, to obtain a true picture of the amount actually necessary for kill, the amount absorbed should be determined shortly after an insect dies.

Winteringham *et al.* (1951) used the radioactive bromine analog of DDT in studies on house flies. They applied acetone solutions to the dorsal surface of the thorax of susceptible flies at a rate of 0.4 μgm and to resistant flies at 10 μgm per fly. After 5 hours the susceptible flies had absorbed 29 per cent and the resistant flies 5 per cent of the total weights of the toxicant applied. After 48 hours the susceptible flies had absorbed 50 per cent and the resistant flies 6 per cent of the total weight applied. Twenty-three per cent was recovered as the ethylene derivative after 5 hours and 57 per cent after 24 hours. There was no evidence of the presence of the acetic acid derivative. When the toxicant was applied topically, 8.7 per cent of the amount absorbed was recovered in 24 hours. The presence of piperonyl cyclonene appeared to inhibit the metabolic dehydrohalogenation. The authors suggest that the metabolism of the toxicant is due to enzymes and that the enzyme system is either destroyed or becomes inaccessible on disintegration of the tissue.

Hansen *et al.* (1944) studied the action of radioactive bromine homolog of DDT in insect tissue. They applied 60 cu. mm. (about 3.6 mg.) per cockroach, and after 24 hours washed the insect in alcohol and dissected. Portions of the organs, including the brain, alimentary canal, malpighian tubules, and reproductive organs, were exposed to x-ray film for 250 to 360 hours. The radioautographs showed that the material was present in various organs of the insects, including the nerve cord and brain.

Workers in England have used radioactive insecticides to trace the fate of insecticides in treated foodstuffs and in insects (Anonymous 1950). By this means less than 0.05 μgm of methyl bromide could be determined to within a few per cent. Methyl bromide residues of the order of 0.01 p.p.m. could be estimated with similar accuracy. A method has been developed for the continuous measurement of absorption rates for radioactive methyl bromide by various substances. Radioactive methyl bromide is also being used in the microscopic location of fumigant taken up by insects exposed to the vapors.

Studies of the penetration of radioactive DDT through the cuticle of house flies were conducted by Lindquist *et al.* (1951). Either the toxicant was applied to the top of the thorax of resistant house flies at a rate of 15 μgm per fly or the flies were exposed to a residue of the poison. After 24 hours the flies were washed in acetone to remove exterior DDT and macerated and the DDT or metabolites were extracted with acetone. The topically treated surviving flies absorbed on an average 2.1 μgm of the toxicant whereas those that died absorbed 2.3 μgm. Ap-

proximately 82 per cent of the applied dose remained on the exterior. Those surviving the residue treatment absorbed 0.21 μgm and the dead flies 0.26 μgm of the toxicant, or about one-tenth as much as the topically treated flies.

Bioassay of these resistant-fly extracts with mosquito larvae indicated that approximately 63 per cent of the total DDT absorbed by the topically treated surviving flies was nontoxic and therefore probably metabolized. In the dead flies 71 per cent of the DDT was indicated to be metabolized. The residue-treated flies showed approximately the same degree of metabolism. Bioassay of susceptible flies treated with 0.2 and 0.5 μgm of DDT showed that approximately 31 to 71 per cent of the amount that penetrated the cuticle was metabolized to a nontoxic product, which appears to be a rate somewhat similar to that occurring in resistant flies.

Further studies by Lindquist, *et al.* (1951) showed that approximately 25 per cent of the DDT or metabolites in topically treated flies was located in the internal organs and 75 per cent in the cuticle-hypoderm. The body fluids contained about 10 to 12 per cent of these radioactive chemicals. Flies exposed to DDT residues showed a similar distribution but in smaller amounts.

Roan *et al.* (1950) investigated the mode of action of four organic phosphorus insecticides that had P^{32} incorporated in the molecule. They found the highest concentration of tetraethyl pyrophosphate or its metabolites in the foregut, and the concentration in the blood to rise rapidly at first and then fall sharply. The foregut exhibited a marked selective absorption of this toxicant or its metabolites and a rapid secretion into the gut lumen.

Radioactive carbon is being used in studies on mealybug wilt of pineapple plants (U. S. Atomic Energy Commission 1951). This radioisotope is used to study substances in the salivary secretions of mealybugs, the translocation of these secretions in resistant and susceptible strains of pineapple plants, and to determine whether there is any correlation between the onset of wilt and the time of translocation of salivary secretions to the roots.

Radioactive insecticides should be of great value in studies of their toxicity to warm-blooded animals. The amounts stored in fat and other tissues, secreted in milk, and eliminated in other ways could be accurately determined by the tracer techniques.

Ecology.—There are many ways in which radioisotopes can be used in ecological investigations, as entomologists become more familiar with their possibilities. The most important application in such studies appears to be the tagging of insects and later recapturing and identifying the tagged specimens with Geiger counting equipment. The tagging procedure can be used in studies on flight, movement, or migration in or on the soil, in foods, feeds, plants, and perhaps in or on animals. Insect populations in a locality can be determined from the ratios of tagged to untagged specimens. The release of known numbers of tagged specimens and subsequent recapture of tagged and untagged insects will serve as a basis for calculating population densities. The same method can be used to measure the effectiveness of control operations.

In habit or life-history studies the method should have value. The tagging of some individuals in insect colonies to differentiate age groups for certain response studies appears possible. It is believed that students of social insects could make use of the tagging method. Perhaps drift of domestic worker bees and drones from hive to hive or from field to field could be studied more accurately than heretofore.

The radioactive material to use in any situation will require consideration of safety to man, the half-life of isotope, the type of radiation, emission, and physical properties of the material—i.e., how it can be applied in or on the insect. Perhaps one of the most useful materials is phosphoric acid (or its salts) containing P^{32} (radioactive phosphorus), but since this substance has a half-life of 14.2 days its usefulness is limited to studies requiring more than 50 to 80 days. Other materials used for tagging purposes are Sr^{89}, Zr^{95}, Ra^{226}, and Co^{60}.

In the field of flight of insects Jenkins & Hassett (1950) tagged 3 million larvae of the mosquito *Aëdes communis* D. with radiophosphorus near Churchill in the Hudson Bay Region, Canada. Recoveries of tagged specimens were made for 1 month at distances up to 1 mile from the release point.

Thurman *et al.* (1951) tagged approximately 400,000 mosquitoes with radioactive phosphoric acid, about 99 per cent of which were *Aëdes nigromaculis* (Lud.) near Turlock, Calif. Recovery of mosquitoes was made with light traps set around the release area and by means of aspirator collections on persons. A total of 475 tagged mosquitoes were recovered. Seventeen specimens were taken between 0.75 and 1 mile from the release point and 10 between 1 and 2 miles.

Lindquist *et al.* (1951) tagged several thousand reared house flies and blowflies with radioactive phosphoric acid and released them in a flat agricultural area near Corvallis, Oreg. The recapture was made in screen-wire traps baited with decomposing liver and fermented sugar. Of approximately 36,000 *Musca domestica* (L.), 15,000 *Phaenicia sericata* (*Meig.*), and 1200 *Phormia regina* (Meig.) flies released, 4.6, 3.6, and 14 per cent of the respective species were recaptured. *M. domestica* was recovered 12 miles, *P. sericata* 4 miles, and *P. regina* 8 miles from the center. The flies spread out in all directions even though there was a wind from the northeast.

Arnason *et al.* (1950) attached pieces of radioactive cobalt metal to wireworms and traced their movements in soil with a Geiger-Mueller tube.

In preliminary laboratory studies S. C. Jones[1] determined that the cherry fruit fly, *Rhagoletis singulatus* (Loew.), would ingest radioactive phosphoric acid in sucrose solutions with no apparent harm. The flies retained detectable amounts of radioactivity up to 1.5 months after treatment. It therefore appears that the method will be useful in studies on dispersion of the cherry fruit fly in and around orchards.

Other Applications.—Insects have been used for many years by geneticists in studies of the effect of x-rays on genetic changes. A large amount of literature is available on genetic changes in fruit flies (*Drosophila*) due to x-ray treatment. Muller (1950) has reviewed the radiation damage to *Drosophila* by x-rays and used the data as a basis for forecasting the possible effect on humans of exposure to radioactive materials and x-rays. This work has pointed out dangers of exposure and possible injury to genes which may not show up in the human population for many years.

There is no doubt that insects differ greatly in the amount of radiation they need to cause either immediate or delayed mutations. Blumel (1950) reared *Drosophila* in a medium containing 16.5 microcuries of radioactive phosphorus per milliliter, and found several mutations in *D. virilis* in the next generation. Hoffman *et al.* (1951-a) found no abnormalities in any stage of house flies reared in a medium containing 2.4 microcuries of radioactive phosphoric acid. The flies appeared to be normal for three generations thereafter. Adult flies fed sugar solutions containing radioactive phosphoric acid showed up to 100,000 counts per minute without apparent injury except sterility in some cases. Growth and metamorphosis in insects are sometimes retarded or inhibited by exposure to radioactive substances. Hassett & Jenkins (1949) found that P^{32} retarded the growth and pupation of mosquito larvae.

Reproduction of an insect may be increased by exposure to low-level radiations. Rodriquez (1948) found that more mites were produced when reared on bean plants containing P^{32} than those on control plants containing P^{31} (nonradioactive phosphorus).

Consideration should be given to the possibility of producing sterile females or males of a species for release in an area as a means of control. The continued release of a preponderance of sterile males in an area harboring a low population of a species might result in a complete eradication, provided, of course, the sterile males would satisfy the mating instinct of the normal females present. Bushland & Hopkins (1951) determined that a dosage of 2500 roentgens sterilized male screwworm flies. When sterilized males were confined with normal females and normal males in laboratory cages, most of the normal females did not produce fertile eggs if the ratio of sterilized males to normal males was 5 or 10 to 1. Laboratory observations showed that males will mate as many as 11 times if virgin females are available but most females will mate only once.

Radioisotopes will perhaps be useful for

[1]Personal communication.

studying the physical properties of insecticide emulsions and suspensions. Rates of settling and amounts of toxicants taken out of emulsions by dipping wool, hair cloth, and other substances could be determined in laboratory tests.

The distribution of sprays or dusts applied with various types of equipment might be studied. Swath patterns and swath widths could be determined easily and quickly if the spray or dust contained a radioactive tracer. Before such studies could be initiated a careful analysis of the hazards involved should be made. With ample safeguards such tests could perhaps be conducted in an isolated place with an isotope of short half-life such as radioactive phosphoric acid incorporated in the dust or mixed with the spray.

Laboratory or small-scale field tests could no doubt be conducted to determine the spread and depth of penetration of sprays on various types of leaf surfaces.

SUGGESTIONS ON INITIATION OF STUDIES WITH RADIOACTIVE MATERIALS.—The following material is presented for the benefit of entomologists who would like to pursue studies in this field but are not familiar with procedures and equipment. It is hoped that the suggestions will be of value in stimulating efforts towards the use of radioisotopes in entomological research.

Source of radioactive materials.—The U. S. Atomic Energy Commission is responsible for the distribution of all radioactive materials. The pile at Oak Ridge (Tenn.) National Laboratory is the major source of radioisotopes. They are obtainable from the Commission or from authorized industrial concerns or educational and research institutions. The Isotopes Division of the Atomic Energy Commission grants authority for their purchase and use to qualified persons after an examination of the facilities available and uses to be made of the materials. All users are required to have instruments for (1) the accurate measurement of radioactivity and (2) proper monitoring to insure safe radiation levels and to locate and measure radio-contamination.

Negotiations may be made directly with the Atomic Energy Commission, but entomologists may find it more efficient and convenient to work with and through trained personnel in nearby colleges, universities, or industrial concerns who are trained in the problems of safety, procurement, and measurements and can make dilutions of materials having high radioactivity so that they can be used with reasonable safety in biological studies. The Commission maintains a list of qualified consultants in each area who are ready and willing to help any scientist in isotope research.

Equipment.—The question is frequently asked—how far can radioactivity be detected with suitable instruments? In the usual biological work where diluted materials containing beta particles are present, the Geiger-Mueller tube will detect radioactivity at a distance of 0.25 to several inches, depending upon the source. Isotopes containing dangerous and highly penetrating gamma rays can be detected even though shielded by several inches of soil and other substances.

Equipment for detecting radioactivity in biological research can be elaborate and expensive, but it is possible to perform some work with an inexpensive laboratory monitor equipped with a Geiger-Mueller tube. This instrument is useful in flight studies where collections of insects are examined to determine those having radioactivity. Semi-quantitative measurements can be made easily and rapidly. Portable battery-operated devices for outdoor use are also available.

In most biological tracing work the administered sample is greatly diluted and tissues or parts are therefore of weak radioactivity. In such cases a thin-window Geiger-Mueller tube attached to a commercial scaler is necessary.

For more exact work with compounds containing the weak beta emitter C^{14} (present in radioactive DDT), a gas-flow counter is highly desirable. The instrument is extremely sensitive to radiations of a low level and is well suited to studies with DDT, which at present has a low specific radioactivity. It is from 8 to 12 times more sensitive than the Geiger-Mueller tubes. Although expensive, it costs less than a low-priced automobile or light truck.

Radioautographs are images of the radiations emitted by radioactive substances on photographic film. Sections of the plant or animal are dried and pressed into close contact with photographic film.

The radiations from the sections produce an effect on the film similar to that caused by visible light, and when the film is developed the radioactive element is indicated by the darkened areas. The exposure period varies with the amount of radioactive material in the section. Radioautographing is widely used in studies of translocation of elements in plants and animals.

CONCLUSION.—In conclusion, let me reiterate the belief that entomologists can make good use of radioisotopes in studies on the biology and control of insect pests. Radioactive tracing studies and techniques will not solve all problems or provide a simple short-cut road to miraculous discoveries. Close cooperation with the physiologist, chemist, and others is essential in physiological and toxicological studies in order to reach the final explanations of life processes. Experimental work must be carefully designed, initiated with painstaking attention to details, and conducted with a vigilant surveillance so as not to overlook pertinent factors or misinterpret results. Even with close scrutiny it is expected that some errors and incomplete interpretations will result. This should not deter the researcher to a do-nothing policy, because it is believed that public and scientific opinion will look with favor upon new methods, procedures, and ideas as long as they are basically sound.

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Field Studies with New Acaricides to Control Citrus Bud Mite[1]

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The citrus bud mite, *Aceria sheldoni* (Ewing), is a serious pest of lemons in the coastal districts of California, and frequently is injurious to oranges in these areas. The distribution, biology, and plant injuries of this eriophyid have been described by Boyce & Korsmeier (1941). These workers also reported results of studies on control of this mite with petroleum oil and sulfur (separately and in combination), as well as with various sulfur compounds, such as lime sulfur and ammonium polysulfide, and with the triethanolamine salt of 4,6-dinitro-2-cyclohexylphenol (TEADN) and HCN fumigation. They found HCN fumigation to be ineffective against this pest. Sulfur, sulfur-oil combinations, and TM-1, although relatively effective, were found to be phytotoxic under some conditions. Because petroleum oil was effective not only against the citrus bud mite but also against other citrus pests, it has come into general use for control of this mite. There are many situations in citrus culture, however, in which it is inadvisable to apply petroleum oil sprays. Studies directed toward finding a substitute chemical control treatment were therefore undertaken and are reported herein.

In most groves where citrus bud mite causes injury to lemon or orange trees, the citrus red mite, *Paratetranychus citri* (McG.), is a potential or serious pest. The effects of a compound upon citrus red mite populations must therefore be considered in the process of selection for citrus bud mite control.

METHODS AND MATERIALS.—Since a satisfactory laboratory method of rearing the citrus bud mite has not been developed, all chemical control studies were made in the field. Boyce[4] studied methods of evaluating populations of citrus bud mite and found that the most suitable procedure was to ascertain the percentage of buds infested with mites. In the present studies mite populations were not evaluated until sufficient time had elapsed to permit samples to be taken from buds that developed after chemical applications had been made. Mite populations treated in the fall were not evaluated until new growth had developed the following spring. However, if chemical applications are made in the spring or summer, sufficient new growth for mite evaluations may develop in 2 to 3 months.

For evaluation of the effectiveness of new materials in reducing citrus bud mite populations, samples of 10 new-growth terminals that were sufficiently mature to be favorable for the mites were taken from each of eight sample trees. Five buds from each terminal were dissected under magnification (×20) to ascertain the presence or absence of mites. Results are reported as percentages of infested buds.

This method of evaluating citrus bud mite populations has certain limitations. For example, climatic or biotic factors intervening in the period between treatment and sampling may eliminate differences in population levels due to the effectiveness of the treatments. Additionally, the time of sampling must be carefully anticipated by presample evaluations. The buds must be sufficiently mature to be favorable as a habitat for the mites, and they must be sampled when the original migration from old buds or fruit buttons (calyxes) to new buds has just been completed.

By recording data in terms of percentages of infested buds, the tedious labor of counting these small mites is avoided, and the evaluation process is greatly expedited. Sampling of new buds provides a more accurate measure of the relative effectiveness of chemical treatments than sampling of buds or fruit buttons present at the time of treatment.

Sprays were applied by means of standard orchard spray rigs equipped with high-pressure reciprocating-type pumps and manually operated spray guns. A tower was used where adequate coverage was not readily obtained by spraying from the ground.

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[3] The author wishes to thank all those who have cooperated in these studies, and to acknowledge especially the assistance of M. J. Jesser and J. O. Complin.

[4] Unpublished data on file at the University of California Citrus Experiment Station, Riverside, California.

At least two trees were used in preliminary screening tests of each new material for citrus bud mite control. When a high percentage of infested buds resulted from such trials, the material or formulation involved was eliminated from further consideration. Materials giving fair to good control in initial tests were studied more extensively. Where possible, both emulsive, or emulsion, and wettable-powder formulations were included in initial tests.

RESULTS.—The degree of citrus bud mite control (good, fair, poor or none) obtained with 44 different materials in preliminary field trials is shown in table 1. Only five of these materials showed sufficient promise to warrant extensive study: namely, the dicyclohexylamine salt of 4,6-dinitro-*ortho*-secondary-butyl phenol[1] di-2-ethylhexyl phthalate, DDT, chlordane, and 2-(*p-tert.*-butylphenoxy) isopropyl 2-chloroethyl sulfite.[2]

Results of applications of these five materials and parathion, under a variety of field conditions, are compared in effectiveness with a standard petroleum oil spray in table 2.

DISCUSSION.—Although petroleum oil sprays were generally more effective than the dinitro treatments, adequate control was obtained with the latter material in a sufficient number of instances to warrant its use under certain field conditions. Some injury to young lemon foliage has resulted when treatment was followed by a period of hot weather. This material has not been made available for commercial usage.

Di-2-ethylhexyl phthalate, used at 1 quart per 100 gallons of spray, was as effective as petroleum oil for control of this mite, and dosages of 2 quarts were generally more effective than the oil. However, even applications of the lower dosage of this material appeared to produce many of the same objectionable responses of citrus trees and fruit as petroleum oil sprays. Other citrus pests such as black scale, *Saissetia oleae* (Bern.), and California red scale, *Aonidiella aurantii* (Mask.), are not controlled as effectively with this material as with petroleum oil. For these reasons, di-2-ethylhexyl phthalate has not been used commercially to supplement or replace petroleum oil for control of citrus bud mite.

Table 1.—Degree of citrus bud mite control obtained with various materials in preliminary field trials.

MATERIAL	FORMULATION[1]
Good Control	
Dicyclohexylamine salt of 4,6-dinitro-*ortho*-secondary-butyl phenol (DN-211)	WP
Di-2-ethylhexyl phthalate	E
DDT (in kerosene)	E
Chlordane	E and WP
2(*p-tert.*-butylphenoxy) isopropyl-2-chloroethyl sulfite (Aramite)	E and WP
Fair Control	
Ethyl-*p*-nitrophenyl thionobenzene-phosphonate (EPN)	E and WP
Xanthone	WP
Methylated naphthalenes (AR-70)	E
Dioctyl furmarate	E
Dioctyl sebacate	E
Lethane 60 (beta thiocyano ethyl esters of alphatic fatty acid, 50%)	E
Octamethyl pyrophosphoramide	
Parathion	
Poor Control or None	
2,2-Bis-(*p*-butoxyphenyl) propane	E
1,1-Bis-(*p*-chlorophenyl)-ethanol (DMC)	E and WP
Lorol-2-thiazolinyl sulfide	E
Bis-(*p*-chlorophenoxy)-methane	E and WP
p-Chlorophenyl-*p*-chlorobenzene-sulfonate	E and WP
Dicyclohexylamine salt of 4,6-dinitro-*ortho*-cyclohexylphenol	WP
4,6-Dinitro-2-caprylphenyl crotonate	WP
2,4-Dichlorophenylbenzenesulfonate	E and WP
p-Chlorophenyl phenylsulfone	E and WP
1,1-Bis-(x-chlorophenyl)-ethane	E
Hydroxypentamethylflavan	WP
Toxaphene	WP
Benzene hexachloride	WP
Aldrin	E and WP
Dieldrin	E and WP
1,1-Dichloro-2,2-bis-(*p*-chlorophenyl)-ethane	WP
Diphenyl oxide	E
Diphenyl amine	E
Piperonyl cyclonene	E
Benzol benzoate	E
Thialdine	E
N-butyl butyrol thialdine	E
Phenothiazine	WP
Phenothioxin	E
Polyethylene polysulfides	WP
Methyl N-amyl ketone	E
Tetraethyl pyrophosphate	E
Tetraethyl dithiopyrophosphate	E
S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate	E and WP
0,0-dimethyl-S-(2-oxo-ureidoethyl)-dithiophosphate	

[1] E = Emulsive or emulsion; WP = wettable powder.

[1] DN-211.
Aramite.

Table 2.—Effectiveness of selected spray materials compared with that of conventional applications of an aqueous emulsion of 1.75 per cent medium-grade petroleum spray oil for control of the citrus bud mite.

Spray Material	Dosage per 100 Gal. Water[1]	Formulation[2]	Total No. Experiments	No. Experiments in Which Treatments for Citrus Bud Mite Control Was—		
				Better than Oil	Equal to Oil	Poorer than Oil
DN-211[3]	0.2 lb.	20-WP	9	2	0	7
Di-2-ethylhexyl phthalate	2 qt.	E[4]	21	10	2	9
	4 qt.	E[4]	7	5	2	0
DDT	1 lb.	E[5]	11	5	1	5
	2 lb.	E[5]	11	6	2	3
Chlordane	1 lb.	E[5]	4	3	0	1
Aramite[6]	0.25 lb.	15-WP	8	1	2	5
	0.5 lb.	15-WP	10	1	2	7
	0.25 lb.	E[7]	6	1	1	4
	0.5 lb.	E	7	3	1	3
Parathion	0.5 lb.	25-WP	6	0	0	6
	1 lb.	25-WP	5	1	2	2

[1] Technical material.
[2] WP = wettable powder (percentage); E = emulsion.
[3] Dicyclohexylamine salt of 4,6-dinitro-*ortho*-secondary-butyl phenol.
[4] Emulsified with 4 oz. blood albumin spreader per 100 gal. water.
[5] Dissolved in 3 gal. of a solvent mixture containing 25 parts kerosene and 1 part dimethyl naphthalenes, and emulsified in 100 gal. water with 4 oz. blood albumin spreader.
[6] 2-(*p-tert.*-butylphenoxy) isopropyl 2-chloroethyl sulfite.
[7] A polyethylene ether of a long-chain fatty acid was used as the emulsifier.

Kerosene emulsion formulations of either DDT or chlordane have controlled this mite effectively, but since applications of these two materials generally result in an increase of citrus red mite, their use for citrus bud mite control is not expedient.

At practical dosage levels, parathion has been relatively ineffective for control of citrus bud mite in most tests. When parathion is applied for control of California red scale, an initial and temporary reduction of citrus bud mite populations may occur.

Jeppson (1951) reported that Aramite is an effective acaricide for control of citrus red mite. Although the data indicate that Aramite is not as good as oil for control of citrus bud mite, its effectiveness against citrus red mite, combined with its efficiency against citrus bud mite, is sufficient to make it a material of choice in many instances to supplement petroleum oil.

At the present time Aramite appears to be the only one of the materials evaluated that may be used effectively against the citrus bud mite in California. This material has been applied extensively for commercial control of both citrus red mite and citrus bud mite.

SUMMARY.—In preliminary field screening tests with forty-four different spray materials, only five resulted in effective control of the citrus bud mite: namely, the dicyclohexylamine salt of 4,6-dinitro-*ortho*-secondary-butyl phenol,[1] di-2-ethylhexyl phthalate, DDT, chlordane, and 2-(*p-tert.*-butylphenoxy) isopropy 2-chloroethyl sulfite.[2] For reasons indicated, aramite appears to be the only one of the materials that may be used effectively in California for control of citrus bud mite.

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Jeppson L. R. 1951. New acaricides for control of citrus red mite, 1948–1950. JOUR. ECON. ENT. **44**(6): 823–32.

Recent Developments in Oriental Fruit Fly Research[1]

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Research on the oriental fruit fly *Dacus dorsalis* Hendel, has now progressed through its second year of expanded activity. The organization of these investigations has been described in a previous paper (Carter 1950). It is the purpose of the present paper to review the current status of this research and to evaluate the results achieved in relation to the original objectives of the Investigations. These objectives were the result of an emergency created by the arrival of *D. dorsalis* in the Hawaiian Islands. This fly proved to have a large host range and an extremely high potential population, which developed at an alarming rate. The emergency was both local and national, the latter being recognized as of paramount importance.

The first conceivable emergency was that of an incipient infestation appearing in a mainland area, probably in California. It was considered essential, therefore, to develop techniques for eradication of such an infestation, to be based initially on the findings of a chemical control section and expanded by an area control unit.

The second emergency would be a corollary of the first and would involve quarantines against movement of commodities out of an infested area. This restriction was an accomplished fact in Hawaii. Quarantines already established against the Mediterranean fruit fly, *Ceratitis capitata* (Wied.) and the melon fly, *Dacus cucurbitae* Coq., were strengthened and made more inclusive as host-range data accumulated.

The progress made toward meeting these emergencies can now be briefly described.

First is the reduction of populations by parasites. The huge infestations of 1948 are now no longer found and, although there was evidence of a decline in population levels before the introduced parasites were well established, there can be no doubt that the latter are responsible for the current low levels of fly infestation in the major host.

During the last 2 years more than 3,790,000 fruit fly pupae have been collected from at least 10 tropical areas throughout the world, and work is currently going on in Siam, North Borneo, Brazil, and West Africa. From these pupae 158,000 living specimens of parasites have emerged, including 47 species of opiine wasps and 22 other species.

The first parasite established was *opius longicaudatus* (Ashm.), reared from material sent in by Krauss from Malaya. The establishment of this parasite was rapid and most promising, although it now occupies a minor position. A second species from the same area, first called *O. persulcatus* (Silv.), was bred out in quarantine in what appeared to be two color forms. Since it was agreed that there was no danger of secondary parasitism with the opiines, field releases were made directly from quarantine in addition to furnishing stocks to the mass rearing laboratory of the Territorial Board of Agriculture and Forestry.

These releases proved to be most fortunate. One of the color forms failed to survive long in the laboratory but was recovered in the field. It is now recognized as a distinct species, *Opius oophilus* Full., and has become the predominant opiine in the Islands, owing, it is believed, to its habit of ovipositing in the egg of the host. The other form, now well established, will shortly be described by Fullaway as a new species, *O. persulcatus* being an early misidentification.

These three species provide a parasite complex that has so reduced infestation in guava, the commonest wild host of *Dacus dorsalis*, that uninfested fruits are commonly found and heavily infested fruits are rare. This complex appears to be so promising that there is some concern about the possible deleterious effects of new introductions.

One other *Opius* species, *O. incisi* Silv., has been recovered in the field.

Of particular significance is the evidence that the species of *Opius* that attack *Dacus dorsalis* will also attack *Ceratitis capitata* but not *D. cucurbitae*.

[1] Presented at the meeting of the Pacific Slope Branch of the American Association of Economic Entomologists at Seattle, Wash., June 19–21 1951.

Laboratory data are now being confirmed in the field, particularly on the Island of Lanai.

The more recent explorations in North Boreno have uncovered another valuable addition to the parasite complex. *Opius "North Borneo #4"* is apparently an effective parasite of *Dacus cucurbitae* in the laboratory and has been released in large numbers. *O. watersi* Full., bred from cucurbits (luva) in India, has been recovered from the melon fly in the field.

Biological control has, therefore, materially reduced populations of the oriental fruit fly and by so doing has reduced but not eliminated the possibility of chance infestations reaching California. Quarantine requirements must still be rigidly adhered to.

Biological control can also serve emergency needs by the development of techniques for the mass rearing of parasites. A study by the University of California Unit required much basic information, which will be referred to later in this paper, but the end result is that the production of host eggs and the culture of host larvae in a stable medium has been worked out, and the culture of the important parasites of *Dacus dorsalis* and *D. cucurbitae* and the obtaining of satisfactory sex ratios has been shown to be possible. Since the plan of campaign developed by the California State Department of Agriculture envisions the use of mass-produced parasites as part of the control program, the work of the University of California Unit is a real contribution to emergency techniques.

It is expected that foreign exploration for parasites will have been completed and all the explorers withdrawn before the end of the current calendar year.

In the event of a mainland infestation two steps would be taken. The infested area would be quarantined and an eradication program embarked upon. Such a quarantine would involve huge losses unless the means were at hand to permit movement of fresh fruits and vegetables out of the area.

There have been three major contributions to this first problem. Host-range studies have established the host status of all the important California commodities. Many are either unsuitable or only rarely infested under conditions of extreme population pressure.

Recent advances in commodity treatments will make it possible to greatly simplify the problem of shipping commodities. While the standard vapor-heat and methyl bromide treatments will be available, the discovery that ethylene dibromide is an effective fumigant is possibly the most important datum in this field. Toxic to insects at extremely low concentrations, it is also noninjurious to a wide range of commodities, a fact confirmed by extensive studies by workers in California.

The third contribution to the quarantine emergency is necessarily in the preliminary stages, but valuable none the less. Field stations on the islands of Maui and Hawaii are determining the physical factors of the environment, which limit the distribution, not only of *Dacus dorsalis* but also of *Ceratitis capitata* and *D. cucurbitae*. It is known that the preoviposition period is extremely sensitive to low temperature. Flies may live as long as a year where temperatures rise high enough to permit them to feed, but may never develop eggs unless fed fortified diets. The mating temperature is also significant, coupled as it is with a requirement for low light intensity. The combination of preoviposition and mating temperature requirements may well prove to be the limiting factors to establishment in many mainland areas. The old concept of threshold of development must be modified, and thresholds for each stage and phase of the insect's biology must be substituted.

There are, naturally, limitations to the climatic types available in Hawaii, but the testing of *Dacus dorsalis* under mainland temperature and humidity conditions is now under way.

The equipment for this study represents a distinct advance in biological instrumentation. Original temperature and humidity records are transferred onto suitable control instruments that function in a "walk-in" chamber large enough to accommodate three large cages, a number of holding boxes, as well as an operator. With only slight deviations from the original record, the spring hygrothermograph charts from Oceanside, Fresno, and Riverside, Calif., Charleston, S. C., and Fort Pierce, Fla., are being duplicated. One cabinet is being run on the Haleakala (7200 feet) station on Maui, where in-

tensive field studies have been made. This will serve as a check.

Significant data are accruing. Under Oceanside conditions immature flies have failed to complete the oviposition period and gravid flies finally produced a small brood of smaller-than-average flies after 59 days. These are for spring (March-May) conditions. On the other hand Fort Pierce conditions for the same period appear to be ideal for the development of large *Dacus dorsalis* colonies. If this actually occurred, there would be the very strong possibility of migration northward as the summer advanced, thus creating a situation similar to that existing in Mexico and Texas with *Anastrepha ludens* (Loew).

Temperatures and humidities of the hot interior locations on the mainland that have been reproduced, have been adequate to stimulate growth of a colony, but heavy mortalities are occurring now that temperatures are becoming extreme and humidity low. It is confidently anticipated that in due time probable and possible seasonal distribution maps can be prepared for the continental United States. The value of these maps for quarantine purposes will be inestimable, because it is reasonably certain that most of the area will fall in the safe zone. Maps prepared on the basis of temperature and humidity will, of course, represent the optimum for any one location since, while the physical factors may be suitable, the lack of a host sequence might still be limiting.

In critical areas, marginal for temperature, the longevity of the three species of fruit fly is in the following descending order—*Dacus cucurbitae*, *Ceratitis capitata*, and *D. dorsalis*—and thresholds of development appear to be slightly higher for *dorsalis*. Whether these differences are sufficient to establish a better survival potential for the first two species named is doubtful, but complete comparative studies of the ecology of the species are definitely necessary.

Eradication procedures are based on the work of two projects, chemical control and area control.

Chemical-control studies with the male lure, methyl eugenol, as a control measure clearly indicate that in the event of a mainland outbreak of *Dacus dorsalis* the distribution and operation of at least 25 methyl eugenol-parathion traps per square mile in the affected area would establish its center and outer limits, and provide the most accurate means available of estimating current population abundance. The possibilities of a considerable measure of control being achieved by this method are very real.

A second eradication measure would be the application of soil insecticides. Several of these are available and, although large amounts are needed, economy would be sacrificed to effectiveness if necessary.

Residual sprays, many of which are already included in spray programs in California and elsewhere, would provide effective controls. Some insecticides, notably parathion, dieldrin, and aldrin, function not only as contact insecticides but also as fumigants several days after application.

The principle of bait sprays has also found application. When fortified with protein hydrolysate and sugar, parathion is many times more effective than when used alone. Furthermore, there is evidence that parathion and possibly other insecticides may serve as lethal contaminants of the insect's food supply.

It is clear from the foregoing that the insecticidal approach to an emergency campaign is well developed.

Extending and simplifying chemical-control data, the Area Control Project first concerned itself with tests in typical infested areas. After approximately 1 year of these preliminaries, operations were started last November on the island of Lanai. This island includes a large, wild guava breeding area, one large town, and two small villages. Because of its isolation it seemed an ideal "type" area for an experimental attempt to eliminate a fruit fly population, at least within the limits imposed by fly movement. It was recognized initially that reinfestation from other islands would occur, and for that reason there would have been little experimental value in applying a single insecticidal treatment over the area.

The operation, however, including as it did four large insecticidal areas of from 400 to 600 acres each in the guava breeding zone, treatments of the villages and other residential areas with dilute and fog sprays, and the treatment of nonhost concentration areas and pineapple fields by both airplane and fog machines, gave

an opportunity for large-scale experimentation, at the same time providing a total treatment of the breeding and concentration areas on the island. Since any eradication program on the U. S. mainland might also include the destruction of crops, chemical defoliation was tried, as well as handgrubbing. Sanitation procedures in the villages were maintained throughout the operation.

The effects of the various treatments were evaluated in two ways, one by bioassays immediately following the treatments and the other by breeding and trapping techniques. Although the use of replicated areas was not possible, the large acreages used for each treatment tended to overcome the main difficulty encountered in small-plot tests; namely, the movement of flies and drifting of insecticides from one plot to another. Actually all the insecticide treatments drastically reduced the fly population and almost eliminated the larval infestation in guava and other host fruits.

Although the Mediterranean fruit fly appeared after the oriental fruit fly was almost completely eliminated, the infestation was very minor. The DDT-parathion combination may be the most feasible of those studied for controlling the two flies together. The oriental fruit fly might have been eradicated with the method employed if reinfestation from neighboring islands had not been an important factor. Evidence from trap catches confirmed and strengthened the data gathered previously with marked flies concerning interisland movements.

Infestation in guava and other host fruit was reduced to almost zero after the initiation of area control procedures. Ripe bananas exposed for 7-day periods in cages in Lanai City, which has been shown to be a great concentration area for flies moving from the breeding areas, remained uninfested for at least 3 months. Fallen fruits, picked up as a sanitation procedure, were sampled to determine their fruit fly populations. Avocados, papayas, guavas, cherries, and bananas in Lanai City showed infestation in November and early in December, but thereafter were entirely uninfested.

For the rapid coverage of large areas of infested fruits, the airplane has proved effective. For rapid elimination of adult populations the fog machine would be a valuable adjunct to control programs, because with them large areas can be covered in a short time. The use of defoliants to prevent the ripening of fruit was successful and almost eliminated the succeeding crop. There is no evidence of permanent damage to the trees.

The details of this large-scale operation are now being prepared for publication.

The emergency aspects of the problem are thus well in hand and will undergo constant refinement. However, where research on a single insect is so adequately supported and is attacked from so many angles, a great volume of data accrues that will be useful beyond the immediate emergency needs.

Studies on fruitfly nutrition, necessary for development of suitable media for mass production of flies and parasites previously mentioned, have had a far-reaching effect on almost every project of the Investigations. Addition of protein to diets has been shown to be essential to normal growth, to completion of preoviposition, and to egg viability. In marginal areas only suitably fed flies have survived, and in insecticide tests there is a relationship between diet and the toxic effects of DDT.

Some fascinating aspects of biological control are well worthy of continued study. Why were *Dacus dorsalis* populations on the decline before the introduction of parasites, and what were the factors involved? This is no new phenomenon in the islands. The Mediterranean fruit fly went through a similar cycle, and many other noneconomic species, notably among the thrips, have followed the same course in recent years; namely a sudden flare-up on introduction, followed by subsidence.

The action of established predators must not be discounted, but the tremendous drop in *Dacus dorsalis* population from 1948 to 1949 cannot be ascribed solely or even principally to predators.

If these factors could be adequately evaluated, a more ordered and objective approach to the problems presented by new insect-pest introductions might be possible. The work on recovery and evaluation being performed by the Hawaii Agricultural Experiment Station is a step in this direction. Recovery studies were necessary to check on establishment of released parasites to relieve the work

of mass breeding, but the status of parasitism and guava infestation became known through this study. Evaluation studies are much more complicated, but it is clear that only a small percentage of eggs laid ever become mature enough to be affected by either parasites or predators.

It seems obvious that fluctuations in the factors causing egg mortality might affect the parasite's capacity to hold populations below economic loss levels.

A much more detailed study is necessary to determine the fluctuations of parasite and host in relation to host species and the seasonal sequence of these species. The area of guava is so vast that effective control in those fruits still leaves a large potential initial population on other and succeeding hosts. These can be significant enough to cause losses on other economic fruits, and it is most probable that production of fruit to commercial standards will require a combination of biological and chemical control. The matter of biological control of guava fruiting is clearly indicated on two grounds: (1) to prevent the encroachment of the tree on range lands, and (2) to reduce the potential host reservoir.

The necessity for comparative studies of all three fly species is indicated by data from all projects. When control, either chemical or biological, reduces *Dacus dorsalis* to negligible proportions *Ceratitis capitata* has reappeared in measurable numbers. What competitive factors are involved and will these *capitata* infestations serve as carry-over reservoirs for *Opius* spp.(?) Answers to the first question are speculative, but there is clear evidence of an affirmative answer to the second.

Chemical control, however, must reckon with all three flies and certainly with *Dacus dorsalis* and *Ceratitis capitata* together. The return of *C. capitata* to sprayed areas indicates differential susceptibility to insecticides. Chemical control must also face the prospect, however unlikely, of permanently established fruit fly infestations on the mainland; and the resistance to DDT that has been shown in the fourth generation of line-bred flies emphasizes the need for alternative insecticides.

It is clear that the migratory habits of the fly will complicate controls. Its habit of drifting from host to host and area to area is characteristic. There is evidence that the opiines also drift freely. Movements have been followed by the use of flies marked with colors, but in future studies gross colonies of radioactive flies will be used.

In the field of lures and repellents there is still no male lure even approximating methyl eugenol for *Dacus dorsalis*. It is not attractive to other species. The fermented sugar-yeast lure is still the standard for both sexes of all three species of fly, but whether it is equally attractive at all times has been challenged by field workers. Certainly it is a measure of activity, but whether it gives an accurate index of total population of each species at any one time is not yet shown.

New work on lures and repellents has been greatly accelerated by a new type olfactometer. This instrument permits fairly rapid screening of test compounds—the study of attractive and repellent fractions of the fermenting lure and of various proteinaceous lures. These last-named have proved greatly superior to the fermenting lure except in the late winter months, a sequence that suggests a seasonal variation in the availability of wild protein food supply.

Microbiological activity also seems to affect proteinaceous lures and this is a very complicating factor. The attractiveness of a fermenting proteinaceous lure may well be the algebraic sum of attractive and repellent constitutents, and the dominance of any one element of the microflora might well determine the end result.

Physiological work on *Dacus dorsalis* is now being carried out with adequate equipment. Intended primarily as an academic section, this work has already brought the finality of exact measurements to such problems as light intensity, the effect of carbon dioxide anesthesia, and the fly's temperature preferenda. The cholinesterase systems of the fly are now under investigation.

SUMMARY.—After 2 years of coordinated cooperative effort, research on the oriental fruit fly, *Dacus dorsalis* Hendel, has progressed to the point where the acute emergency requirements have been met.

Biological control by a complex of highly efficient opiine wasps has so materially reduced *D. dorsalis* populations that the risk of chance migrants to the U. S. mainland has been materially les-

sened. Economic control of infestation in the wild guava fruits has been achieved, but the guava area is so vast that biological control of guava fruiting is indicated to reduce the potential residual populations that attack commercial fruits.

A combination of biological and chemical control will be necessary if fruit growing is to meet commercial standards. The ecological stations on the islands of Maui and Hawaii are determining the physical factors which will limit distribution. It is clear that temperature thresholds for each phase of the insect's biology may be critical, particularly those for preoviposition and mating.

Actual experience in marginal temperature areas is being used as a check on the operation of new instruments which permit the duplication of standard hygrothermograph charts from critical mainland areas. From these data it is expected that reliable potential distribution maps can be prepared.

Chemical control measures are available which include residual sprays, bait sprays, soil insecticides, fog sprays, and a poisoned lure. In combination with the techniques developed by area control these advances give reason for hope that an incipient infestation could be quickly contained and eradicated.

New commodity treatments approved for Hawaiian fruits and vegetables would simplify the problem of movement of commodities from an infested area.

Many fundamental contributions are being made to our knowledge of the biology of fruit flies: the effect of nutrition, the influence of population reduction on competition between fruit fly species, and a critical evaluation of a parasite complex are all current topics. There is clearly a necessity for comparative studies of all three species of fruit fly from the standpoints of limiting environmental factors, their susceptibility to insecticides, their relative reactions to lures and repellents, and their host sequences.

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Decreased Toxicity and Cholinesterase Inhibition in a New Series of Dithiophosphates[1]

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The efficiency of organic phosphorus compounds in controlling many insect species has resulted in their rather widespread application as agricultural insecticides. There are now about six compounds in use. Unfortunately, insecticidal activity of the organic phosphates now employed has been accompanied by high mammalian toxicity. Consequently, studies have been directed toward development of organic phosphorus compounds toxic to economic plant pests, but relatively innocuous to mammals.

It has been reported in the literature that the mode of action of insectidal organic phosphorus compounds containing the phosphoryl or thiophosphoryl group is that of an anticholinesterase (Metcalf & March 1949, Mazur & Bodansky 1946, Chadwick & Hill 1947, DuBois & Mangun 1947). It has been indicated that for this type of compound, there is a direct relationship between *in vitro* cholinesterase inhibition and *in vivo* toxicity to bees, flies, and mice. The few exceptions that have been noted are in the direction of decreased *in vivo* toxicity relative to the *in vitro* activity. These discrepancies can be explained partly by lack of transport to the site of action.

The mechanism involved in the transmission of nerve impulses to the ganglion cells and also in the transmission of motor nerve impulses to the fibers of voluntary muscles appears to be a similar physiological phenomenon for both insects and mammals; namely, through a chemical mediator such as acetylcholine. However, the chemical mediator involved in insect physiology may be not acetylcholine but some closely related substance which may even vary according to the species. As a corollary, the cholinesterases of various organisms may vary in structure and ac-

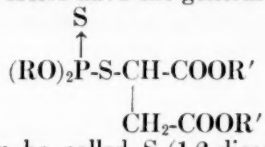
PAID PAPER.
[1] A contribution of the Stamford Research Laboratories of American Cyanamid Company.

tivity. This has been suggested as a means of explaning why 0,0-diisopropyl 0-*p*-nitrophenyl thiophosphate is an effective inhibitor of fly-brain cholinesterase but is not an effective inhibitor of bee-brain cholinesterase (Metcalf & March 1949, 1950).

At least three factors, then, appear to be involved in the toxicity of organic phosphorus insecticides: (1) a chemical mediator (such as acetylcholine), (2) an enzyme (such as cholinesterase), and (3) the transport of an anti-enzyme (such as an insecticide) to a susceptible center in the organism.

Hope that variations do exist in these factors has stimulated research to find organic phosphorus compounds possessing specific toxicity to insects. Such an insecticide apparently has been discovered in a new series of dithiophosphate esters.

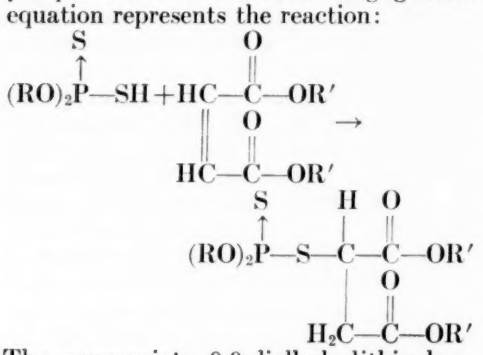
These esters have the general structure



and may be called S-(1,2-dicarbalkoxyethyl) 0,0-dialkyl dithiophosphates. The R and R′ signify alkyl groups and for the compounds reported here are various combinations of methyl and ethyl.

It must be emphasized that the data presented for these new compounds are preliminary and were obtained on technical grade material. Since the completion of the experiments reported here, a specific analytical method has been developed for one member of the series. There is every reason to believe that the quality of the technical materials used was better than 70 per cent.

METHODS.—*Preparation of the dithiophosphate esters.*—The following general equation represents the reaction:



The appropriate 0,0-dialkyl dithiophosphoric acid (0.55 mole), dialkyl fumarate or maleate (0.50 mole), triethylamine (1 ml.), and hydroquinone (0.2 g.) were mixed in an Erlenmeyer flask and placed in a 65° C. oven overnight. Benzene (300 ml.) was added and the solution washed with 10 per cent sodium carbonate solution (200 ml.) and finally with water (200 ml.). After drying over anhydrous sodium sulfate, the benzene solvent was removed under reduced pressure. The oily liquid residue varying in color from pale yellow to light brown was tested as such.

Of the dithiophosphate ester series only malathon[1], S-(1,2-dicarbethoxyethyl) 0,0-dimethyl dithiophosphate (Table 1), has been extensively investigated from the chemical standpoint. It has been purified by low-temperature crystallization and a method of analysis has been developed. This analytical method has indicated that the preparation used in these experiments contained 73 per cent of material possessing the structure listed in table 1.

Entomological Testing Procedure.—Tests on black bean aphid, *Aphis rumicis*, Linn.—All compounds were formulated as wettable powders containing 25 per cent active ingredient and 75 per cent Attapulgus clay. The formulations were suspended in water at various concentrations, and were applied to nasturtium plants heavily infested with *Aphis rumicis*. After holding the sprayed plants on white-enameled trays for 2 days, counts were made. Duplicate plants were used on each concentration.

SETTLING TOWER TESTS ON CONFUSED FLOUR BEETLE, *Tribolium confusum*, DUVAL.—The 25 per cent wettable powders were tested as water suspensions of the desired concentration on *Tribolium confusum* by applying a uniform residue on Petri dishes by means of a settling tower. At each concentration, four replicate dishes containing 25 beetles per dish were employed. Counts were made after 96 hours.

DUST TOWER TESTS ON *Tribolium confusum*.—The 25 per cent wettable powders were diluted with Pyrax ABB talc to prepare dusts of suitable concentrations. Dusts were applied by means of a dust tower to obtain a uniform deposit of five milligrams per Petri dish. Twenty-five beetles were placed on each of four replicate dishes. Mortalities were recorded after 72 hours.

TESTS ON MILKWEED BUG, *Oncopeltus*

[1] Insecticide 4049 in earlier publications.

fasciatus (DALLAS) AND GERMAN COCKROACH, *Blattella germanica* (LINN.).—The dusts were prepared as described under *Tribolium confusum* dust tower tests. Crystallizing dishes, 18 centimeters in diameter, were dusted evenly at the rate of 25 milligrams of dust per dish. Ten insects together with a water bottle were placed in each chamber. Screen covers were used to contain the insects. Duplicate chambers were set up at each concentration and counts were made after 72 hours.

In all experiments, the kills obtained were plotted on logarithmic-probability paper and the LD-50's determined.

Cholinesterase Inhibition.—Data on cholinesterase inhibition were determined by Dr. R. L. Metcalf of the University of California Citrus Experiment Station at Riverside, California. The procedure employed by him has been reported (Metcalf & March, 1949).

Mammalian Toxicity Tests.—Acute oral toxicity determinations on male albino mice were made by The Hazleton Laboratories at Falls Church, Virginia.

DISCUSSION.—*Comparison of Dithiophosphate Esters with Parathion.*—The structures of the experimental insecticides, their relative insect activity, and their acute oral toxicity to male albino mice are summarized in table 1. The insecticidal results based on LD_{50} determinations are expressed in terms of per cent activity relative to parathion.

Table 1, which is self-explanatory, indicates that the most effective dithiophosphates exhibit considerable insecticidal activity although they are less active than parathion. All are less toxic than parathion to male albino mice; the greatest difference existing between malathon and parathion. No correlation exists between toxicity to albino mice and insecticidal activity; for example, technical malathon is one-fourth as active as parathion against *Tribolium confusum* and *Aphis rumicis*, but is one one-hundredth as toxic as parathion to albino mice. Similarly, technical malathon is fairly comparable to Insecticide 4018 in insecticidal action but is about twenty times safer to albino mice. It is evident that malathon combines high insecticidal activity with low mammalian toxicity. It should be pointed out that one could hardly expect to find a compound which would have activity equal to that of parathion for control of plant pests and still have as great a margin of apparent safety as malathon.

On the basis of these data, malathon was chosen for further tests. Preliminary field trials during the summer of 1950 showed that two and one-half to three times the quantity of technical malathon (about 65 per cent grade) was required to give approximately the same control as parathion on many plant pests.

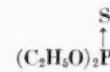
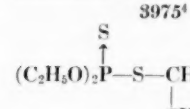
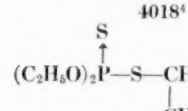
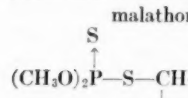
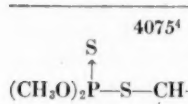
Recent preliminary tests on pure malathon have indicated that the toxicity to *Tribolium confusum* increases with the purity of the compound. Strangely enough there are indications that the toxicity of pure malathon to male albino mice is much less than that of the technical material.

CHOLINESTERASE INHIBITION.—The molar concentrations of parathion and malathon required for 50 per cent inhibition of bee-brain, fly-brain, and mouse-brain cholinesterase have been determined by Dr. R. L. Metcalf and are listed in table 2, columns 2, 3, and 4. The ratio of the molar concentrations for mouse-brain to bee-brain cholinesterase IN_{50} and the ratio of mouse-brain to fly-brain cholinesterase IN_{50} (columns 5 & 6) are greater for malathon than they are for parathion. In columns 7, 8, and 9 of table 2, the anticholinesterase activity of malathon is compared to that of parathion, arbitrarily set at 100. It is readily seen that the anticholinesterase activity of malathon to bee-brain, fly-brain, and mouse-brain cholinesterase is approximately 6.7, 129, and 1.7 per cent that of parathion respectively.

It must be remembered that these are results of *in vitro* experiments at a site of action. Thus, only the inhibitory effect of the chemical at the site of action is determined and other factors such as transport, vapor pressure, and side reactions are eliminated from consideration. These last factors generally have a considerable influence on *in vivo* toxicity determinations.

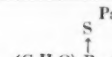
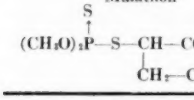
A direct relationship does exist between the anticholinesterase activity of mouse-brain cholinesterase by malathon and the acute oral toxicity to mouse. The molar concentrations of malathon required for IN_{50} of mouse-brain cholinesterase is sixty times that of parathion (column 4, table 2). In column 11, direct acute oral determinations on the mouse indicate good agreement with the anticholinesterase data in that the molar concentration of

Table 1.—Comparison of dithiophosphate esters with parathion.

Compound	Acute Oral Toxicity to Male Albino Mouse[1] LD_{50} Mg. per Kg.	Basic Toxicity Relative to Parathion[2]				
		Aphis rumicis 25% Wettable Powder Test	*Tribolium confusum* Dust Tower Test	*Tribolium confusum* 25% Wettable Powder Test	*Blattella germanica* Dust Chamber Test	*Oncopeltus fasciatus* Dust Chamber Test
Parathion[3] 	9.7	100	100	100	100	100
3975[4] 	250	11	6	—	10	76
4018[4] 	48	45	28	29	17	65
malathon[5] 	930	25	25	24	7	74
4075[4] 	130	25	32	34	5	6

[1] Determined by Dr. L. W. Hazleton, Hazelton Laboratories, Falls Church, Virginia.
[2] The LD_{50} toxicity was determined as p.p.m. or per cent active ingredient. Parathion is given arbitrary rating of 100; hence, a rating of 11 means that the compound is 11% as toxic as parathion.
[3] Purity 97.5%.
[4] Purity better than 70%.
[5] Purity 73%.

Table 2.—Anticholinesterase activity and toxicity of malathon compared to parathion.

Compound	IN_{50} of Brain Cholinesterase[1]					Anticholinesterase Rating[2]			LD_{50} Acute Oral Toxicity to Male Albino Mouse	
				Ratio IN_{50}						
	Bee	Fly	Mouse	Mouse / Bee	Mouse / Fly	Bee	Fly	Mouse	Mg. per Kg.	Mole×10^{-5} per Kg.
Parathion[3] 	1	0.45	2.5	2.5	5.5	100	100	100	9.7	3.3
Malathon[4] 	15	0.35	150	10	42.8	6.67	128.6	1.67	930	282

[1] *In vitro* molar concentration×10^{-6} for 50 per cent inhibition (IN_{50}) of brain cholinesterase.
[2] IN_{50} of brain cholinesterase by parathion is given an arbitrary rating of 100, the other numbers then represent the per cent anticholinesterase activity relative to parathion.
[3] Metcalf & March 1950.
[4] Private communication from Dr. R. L. Metcalf.

malathon required for LD_{50} is about 85 times that of parathion.

With regard to a direct relationship existing between *in vitro* anticholinesterase activity of malathon on bee brain or fly brain and *in vivo* toxicity determinations, there are no *in vivo* data available to make such a comparison. If this relationship were to exist, a quantity of malathon at least 15 times greater than that of parathion would be required for LD_{50} on bees, whereas a quantity only three-fourths that of parathion would be required for LD_{50} on flies. Although the above is speculaton, such a variation in ratio of quantities has been observed in certain *in vivo* tests. For example, the amount of malathon required for German cockroach, *Blattella germanica* (Table 1, col. 6), was 14 times that of parathion while that required for milkweed bug, *Oncopeltus fasciatus* (Table 1, col. 7), was only one and one-third times that of parathion.

However, it has been stated earlier in the discussion that field trials indicated two and one-half to three times the amount of malathon was required to give approximately the same control as parathion for many plant pests. It appears that although malathon is effective against many insects, it may be more selective in its action than parathion. There is some indication that it is effective against some insects that parathion does not control.

SUMMARY AND CONCLUSIONS.—(1) The preparation of a new series of dithiophosphate esters has been reported.

(2) Basic toxicity relative to parathion of four members of the series has been discussed. These compounds are generally one-fourth to one-third as active on insects as parathion and five to one hundred times less toxic to mice.

(3) Among the members of the series reported, there is no direct correlation between toxicity to male albino mice and insecticidal activity. Malathon shows the least toxicity to mice and is practically comparable in insecticidal activity to Insecticide 4018 which is the most toxic to albino mice.

(4) Preliminary data show that although the acute oral toxicity of malathon (65 per cent grade) is about 1 per cent that of parathion (97.5 grade), it is 25 to 30 per cent as toxic to many insects.

(5) Very preliminary results indicate that malathon when pure shows increased toxicity to *Tribolium confusum* but considerably reduced toxicity to male albino mice.

(6) It is possible to synthesize an organic phosphorus compound possessing specific toxicity to insects but being relatively innocuous to mammals.[1]

[1] ACKNOWLEDGMENTS.—The authors are indebted to Dr. L. W. Hazleton for the determination of the acute oral toxicity of the dithiophosphates to albino mice and to Dr. R. L. Metcalf for the determination of cholinesterase inhibition data.

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DDT-Resistance Studies with the Oriental Rat Flea[1]

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With an increasing number of insect species showing insecticidal resistance, the present study was undertaken to determine the possibility of DDT resistance developing in the oriental rat flea, *Xenopsylla cheopis* (Roth). When the study was started no DDT resistance in fleas had been indicated in field operations. In all instances DDT at 5 or 10 per cent in pyrophyllite dust had produced excellent control. Several species of fleas on rats, including *X. cheopis*, were effectively controlled for a 2-month period by one application of 10-per cent dust (Gouck 1946). Dogs were completely freed of several species of fleas by applications of 4 or 5-per cent dusts (Lindquist *et al.* 1944). Fleas were eliminated from house pets and premises by 5 or 10-per cent dusts (Sweetman 1946). Finally, area control of rat fleas was obtained in city campaigns with 5-per cent dust (Ludwig & Nicholson 1947, and Nicholson & Gaines 1948). However, during the summer of 1949, reports of DDT dusts failing to control cat flea infestations were investigated. In several instances, high populations of the cat flea, *Ctenocephalides felis*, persisted even after three applications of 5-per cent-DDT pyrophyllite dusts to infested permises. With the use of a 5-per cent-chlordane dust, the infestations dropped markedly or were completely eliminated.

Although the rickettsia of endemic typhus, *Rickettsia prowazeki mooseri*, has been isolated in nature from *Ctenocephalides felis* (Irons *et al.* 1944), from an epidemiological standpoint the species is not considered to be a proven vector of any infectious disease. DDT resistance in the oriental rat flea, however, would be important in murine-typhus control programs. Therefore, using the oriental rat flea, *X. cheopis*, experiments were set up (1) to determine if DDT resistance could be produced in the laboratory, and (2) to evaluate the importance to field control programs of any resultant resistance.

TECHNIQUE.—A simple rearing procedure was needed for the mass production of uniform test insects. Culture boxes, measuring 24 inches on a side, were made of five-eighth-inch plywood. The inside surfaces of each box were sanded and smoothly enamelled, and a 1-inch overhanging metal flange was added inside the top to prevent fleas from escaping. The bottom of each box was lined with heavy kraft paper. Dry sterile sand, previously sifted through a 32-mesh screen, was added as a layer of 1.5 inches, and 2 ounces of finely ground rat feces were sprinkled over the top of the sand. A container of 14 by 16-mesh screen, 6 inches deep, and fitting the sides and corners of the box, was placed on the sand and was filled with large dry pine shavings. Six ectoparasite-free rats in individual cages were placed on the shavings and approximately 2500 1 or 2-day-old fleas were added.

The rats were fed rat pellets and water-soaked slices of sweet potato for the 3-week period they remained in the culture boxes. The fleas were allowed only a 3-week oviposition period since the first adults of a succeeding generation appeared shortly thereafter under the insectary conditions of 75° F. and 70-per cent relative humidity. At the end of the oviposition period the rats and the screen container of shavings containing almost all of the adult fleas were rapidly removed from the culture box. The sand layer was sifted through a series of four screens having 10, 12, 16, and 32 mesh per inch respectively. Trash was collected on the 10-mesh screen, the cocoons of flea pupae on the 12- and 16-mesh screens and flea larvae on the 32-mesh screen. The sand collected in a box under the screens was returned to the original culture box and the shavings were replaced. Larvae from the 32-mesh screen were returned to the shavings. Usually five siftings over a 14-day period were necessary to collect all the pupal cocoons.

The cocoons were placed in small trays, 6 inches square and 0.375 inch deep, mounted on 3-inch legs. Each tray was placed in an aquarium 18 inches long by 12 inches wide by 9 inches deep, which had one-half of the top covered with organdy, the other half with glass secured with masking tape. Emerging

[1] From the Communicable Disease Center, Public Health Service, Federal Security Agency.

fleas hopped from the tray to the floor of the aquarium. By daily collections with air aspirators, adult fleas of known age were obtained for test purposes. Under normal conditions approximately 15,000 adult fleas were obtained from a colony seeded with 2500 stock fleas.

The following technique was used to select fleas showing the least susceptibility to DDT dusts. A bell jar, 15 inches high and 8.5 inches in diameter, was used as the shell of a dusting chamber. Air for dispersing dust samples was supplied to the chamber through a capillary copper tube centered in the top. The tube extended 3 inches into a 5-inch test tube, 0.5 inch in diameter, which was mounted so that the mouth of the tube was 4 inches below the top of the bell jar. A weighed sample of dust was placed in the test tube, expelled instantaneously by a push-button-controlled air blast, and allowed to settle for 10 minutes on six cardboard disks, 47 mm. in diameter, arranged in a circular pattern on the chamber floor 1 inch from the sides. With a charge of 37.5 mg. of 5-per cent-DDT dust in the test tube, a deposit of 50 mg. dust per sq. ft. (1 mg. per disk) was obtained. The relationship between the amount of dust in the test tube and that on the disks was found directly proportional and quite uniform in a large series of replications.

By use of long-handled tongs, each disk was centered in the bottom of a 3-liter culture flask having slanting sides and a 63-mm. top opening. A 12-inch glass tube, 42 mm. in diameter, was lowered onto each disk. Approximately 150 fleas were poured into the glass tube, thereby producing continuous contact with the dust deposit except when jumping. Five seconds before the end of a desired exposure period, the tube was removed and during the next 10 seconds almost all of the fleas jumped from the disk onto a perforated paper liner in the bottom of the flask. Then the treated

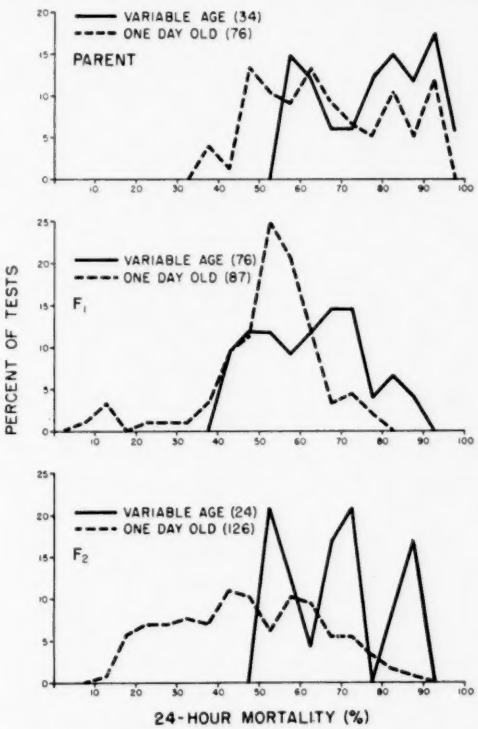

FIG. 1.—Twenty-four-hour mortality (per cent) of adult fleas of the parent, F_1 and F_2 generations after 4-minute exposures to 50 mg. per sq. ft. dust deposits of 5 per cent DDT in pyrophyllite. Variable-age fleas were 1 to 4 days, 1 to 8 days, and 1 to 12 days old in the parent, F_1, and F_2 generations respectively.

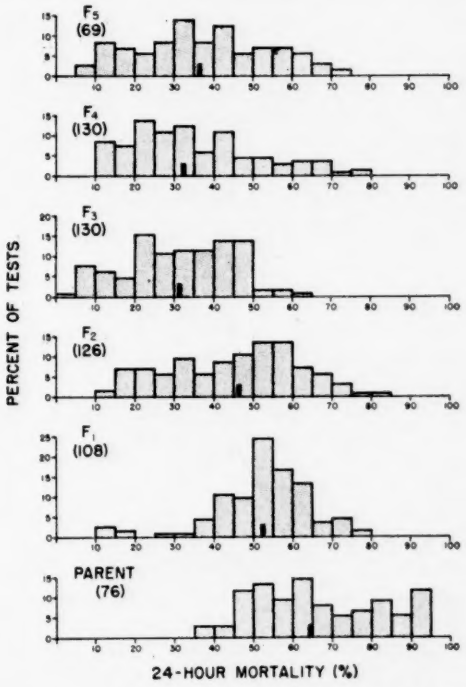

FIG. 2.—Twenty-four-hour mortality of 1-day-old adult *Xenopsylla cheopis* after 4-minute exposures to 50 mg. per sq. ft. dust deposits of 5 per cent DDT in pyrophyllite. Results are expressed as the per cent of the total tests (in brackets) showing given levels of mortality. Mean mortality for each generation is shown as a dark bar.

disk was removed carefully to avoid any loss of dust. The fleas were found to remove less than 0.1 mg. of dust from a given disk. Due to the slanting sides of the flask, the fleas could not escape and a top covering was unnecessary. The insects were held at 80° F. and 70-per cent relative humidity, and the 24-hour mortalities were recorded.

At the time mortality was determined, the live fleas were removed from tests showing a suitable mortality level and were used to seed colonies for a succeeding generation.

The following incidental observations were made on the testing technique:

(a) It was necessary to place a perforated paper liner on the bottom of the holding flask since its omission caused a 5-per cent mortality in control runs with pyrophillite only. Mortality was apparently associated with difficulty of the fleas in maintaining a footing on the slick glass bottom of the flask. With the perforated liner, the mortality in controls was reduced essentially to zero.

(b) Fleas without blood meals gave results essentially equal to engorged fleas and therefore the former were used in all tests.

(c) The adult females in many insect species are less susceptible to insesticides than are the males. In tests made with the rat flea, 57 per cent of the females were killed, as compared to 43 per cent of the males. Since the sex mortalities showed only a slight difference, no effort was made to distinguish mortality by sex in the selection tests.

(d) The addition of water during the 24-hour holding period gave less than 1-per cent difference in mortalities between control lots of fleas with and without water, and it was therefore decided to be unnecessary.

RESULTS.—Adult fleas showing the highest tolerance for DDT were selected for reproductive purposes and these individuals were chosen by exposure to DDT pyrophyllite dust deposits. Using 1-minute exposures and applications of 100 to 200 mg. dust per sq. ft., dusts with 1 to 5 per cent DDT gave complete mortality. Using 1-minute exposures and applications of 50 mg. dust per sq. ft., dusts, with 1, 0.75, and 0.5 per cent DDT gave 72, 58, and 57 per cent mortality respectively. These tests, however, were made without a paper liner in the bottom of the holding flask. After the liner was incorporated into the test procedure, 1-minute exposures to applications of 50 mg. of 1-per cent-DDT dust per sq. ft. gave no mortality. The exposure conditions were then progressively increased using the paper liners in the holding flasks. A series of tests with 50 mg. per sq. ft. applications of 5-per cent-DDT dust at exposure periods of 10, 7.5, 5, 4, and 1 minutes gave mortalities of 88, 80, 73, 65, and 6 per cent respectively. To secure enough individuals in successive generations the 65-per cent selection level was desired. Therefore, conditions of 4-minute exposure to 50 mg. per sq. ft. dust applications of 5 per cent DDT in pyrophyllite were used.

The normal insectary strain of the oriental rat flea was used for initial selection. Large numbers of pupae were obtained and the adults were designated as the parent generation. Ordinarily, enough fleas emerged each day so that most selection tests were made with 1-day-old adults. On week-ends or toward the end of a production cycle, fleas available over several days were combined for selection. In the parent generation these fleas of variable age ranged from 1 to 4 days old. Since only the survivors of the parent generation were used to produce the F_1 generation, the number of F_1 adults available for selection was considerably lower than in the parent

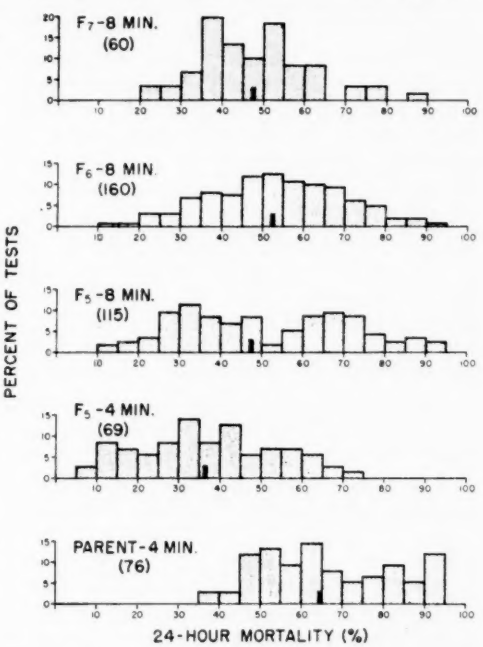

FIG. 3.—Twenty-four-hour mortality of 1-day-old adult *Xenopsylla cheopis* after exposure to 50 mg. per sq. ft. dust deposits of 5 per cent DDT in pyrophyllite. Length of exposure period (after generation title) and average mortality (dark bar) are indicated for the parent, F_5, F_6, and F_7 generations.

generation. Longer periods of daily adult production were combined and therefore the fleas of variable age represent adults 1 to 8 days old. In the F_2 generation the variable-age fleas were 1 to 12 days old.

Comparisons were made between the 24-hour mortalities of 1-day-old fleas and fleas of variable age in the parent, F_1, and F_2 generations (Fig. 1). There was a highly significant difference for the two groups in all cases. The t-test for the parent generation showed a value of 10.847, for the F_1 generation a value of 5.353, and for the F_2 generation a value of 5.535, as compared to a "t" value of 3.291 at the 0.1-per cent probability level. Therefore, from these observations, only results with 1-day-old fleas were used in conclusions and comparisons on DDT-resistance.

The selection conditions of 4-minute exposure to a 50 mg. per sq. ft. application of 5 per cent DDT in pyrophyllite were used for the parent thorough the F_5 generations. Approximately 150 adult fleas were used per replicate. A series of 76 replications in the selection of the parent generation gave an average mortality of 65 per cent. A series of 108 replications gave 53-per cent mortality in the F_1 generation. A series of 126 replications gave 47-per cent mortality in the F_2 generation, while 130 replications in the F_3 generation gave 32-per cent mortality. In the F_4 and F_5 generations, series of 130 and 69 replications produced mortalities of 33 and 37 per cent respectively. Since different numbers of replicates were made in the various generations, the summarized results of the 4-minute exposures (Fig. 2) have been expressed as the per cent of tests showing various degrees of mortality.

In the F_5 generation both 4- and 8-minute exposures to a 50 mg. per sq. ft. application of 5 per cent DDT in pyrophyllite were used for selection of resistant adults. Selections on the basis of 8-minute exposures were continued in the F_6 and F_7 generations, but no further increase in resistance was evident (Fig. 3), and the study was discontinued.

DISCUSSION.—Statistical analyses of variance were done using angular transformations of the mortality percentages of replicates in each generation. For this purpose, the mortality figures were grouped for each 5-per cent-mortality interval. Comparison of the parent with the F_1 generation showed a highly significant decrease in mortality, an "F" value of 47.26. Comparison of the F_1 to the F_2 generation showed a further significant decrease in mortality, "F" value of 13.35. Again from the F_2 to the F_3 generations there was a significant decrease in mortality, "F" value of 94.95. These "F" values all exceeded the 0.1-per cent-probability value of 10.83.

The F_4 generation showed significantly higher mortality than did the F_3 generation, "F" value of 7.83 as compared to the 1.0-per cent-probability value of 6.64. This reversion may have resulted from the low selection level in the F_3 generation where a mean of 68 per cent of the adult fleas survived the exposures. Comparisons of the F_4 and F_5 generations showed no significant change in resistance, "F" value of 1.09 as compared to the 20-per cent probability value of 1.64.

Comparison of the mortalities from the 4- and 8-minute exposures of the F_5 generation showed that the longer exposures produced a significantly higher mortality, "F" value of 23.17 as compared to the 0.1-per cent-probability value of 10.83. Exposures of the F_5 generation for periods of 8 minutes, however, gave significantly less mortality than did the 4-minute exposures of the parent generation, "F" value of 29.02. Comparisons of the mortalities of the F_5 and F_6 generations, and of the F_6 and F_7 generations, showed no significant decrease in mortality, "F" values of 2.77 and 4.50 respectively.

Although a strain of DDT-resistant adults of the oriental rat flea has been selected in the laboratory, the selection conditions are by no means comparable to those occurring in nature. In most cases the exposure of the fleas in the field to DDT-dust applications would be measured in hours rather than in minutes. It has been shown that an increase in exposure time significantly increases the mortality level.

The importance of the exposure period was shown in bio-assay tests run on samples of dust and litter collected from rat runs treated one or two years previously with DDT dusts. Comparisons with known samples showed that complete mortality of adult fleas was obtained after 24-hour exposures to dusts

containing as little as 0.005 per cent DDT. However, no mortality was obtained with dust deposits containing only 0.0005 per cent DDT. Since dust deposits containing only 0.0005 per cent DDT were recovered from the field after 1 or 2 years, it is not possible to predict what type of exposure wild fleas will encounter and thus no predictions can be made as to the possible field development of a resistant strain.

SUMMARY.—A simple rearing procedure for the mass production of adult *Xenopsylla cheopis* in the laboratory has been described. With the procedure, adult fleas of known age may be obtained for test purposes.

A method is described for testing the effect of residual applications of DDT dusts on adult fleas exposed for known periods of short duration. The method has been applied to select adult fleas showing the most resistance to DDT.

Under the selection exerted by 4-minute exposures to 5 per cent DDT in pyrophyllite applied as a dust at the rate of 50 mg. per sq. ft., increasing resistance to DDT was shown by the oriental rat flea through the F_3 generation. No further increase in resistance was shown in tests through the F_7 generation even under selection by 8-minute exposures.

The degree of resistance shown by the laboratory strain of the oriental rat flea was not considered to be of economic importance to field control programs against the species.

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A Device for Recording Insecticidal Knockdown of House Flies and Evaluating Residual Deposits[1]

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Many insecticides now used in space sprays, aerosols, and residual applications have a knockdown or paralytic action upon insects. The knockdown propensities of an insecticide are usually listed as the cumulative effect at the end of a definite exposure period. While this information is useful, it was felt that a preliminary study of the progressive knockdown effectiveness of insecticides might reveal certain factors not shown by the cumulative effects.

The measurement of knockdown demands a method of collecting the insects at definite time intervals after the initial exposure to the insecticidal treatment. Hand collections with air aspirators as performed in standard Peet-Grady space spray tests are dependent upon the operator's skill both as to observation and speed. The operator's skill automatically limits the minimum collection interval and at best represents a combined sample for the total collection time required.

Therefore a tape recorder to measure knockdown rates has been devised. The recorder is entirely mechanical and permits the observations on knockdown to be made progressively and then to be subsequently reread in as small time units as desired. With this apparatus preliminary studies have been made on the knockdown effectiveness of residual deposits of 200 mg. per sq. ft. of various insecticides tested in a room air-condi-

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[4] Biologist.

tioned at 80° F. and 70 per cent relative humidity.

APPARATUS AND TECHNIQUE.—A schematic diagram of the knockdown recorder is given in figure 1. The device consists of two open-bottomed, square, screened fly cages 22 inches on a side mounted on a metal framework which is 22 inches wide by 44 inches long by 30 inches high. The bottom of each fly cage is a four-sided galvanized metal funnel with sides sloping 30° from the horizontal. The outlet of each funnel is a three-eighths-inch centered hole leading into a V-shaped compartment immediately below. Two 1-inch strips of cellulose tape, with the adhesive sides up, are drawn slowly from two reels adjacent to the V-shaped compartment. Each tape passes over rollers mounted on the sloping sides of the V-shaped compartment and the two tapes finally come together at the bottom of the V. The ribbon of double tape, with both outer surfaces nonadhesive, is then wound onto a third reel mounted below. An adjustable set of gears powered by a fractional horsepower electric motor permits two tape speeds, namely 3 feet per hour and 16 feet per hour.

In operation, the sides and top of each fly cage are lined with plywood panels treated with residual applications of test insecticides. Test groups of approximately 400 adult flies are forced by a plunger into each cage through a slotted door. Supplies of food and water are available in containers fastened to the sides of each cage. As the flies are affected by contact with the residual deposits they fall onto the sloping bottom, and, as a result of their struggles, are funnelled into the V-shaped compartment and packaged between the two pieces of tape. The rate of tape movement was checked by placing markers on the outside of the double tape strip at time intervals of an hour or more. Markers were necessary because the build-up of tape on the reel resulted in a gradual increase in tape movement. At the end of the experiment the tape was divided into subunits of time, and the sex and number of flies per unit of time were recorded. The double-cage recorder allows two tests to be made simultaneously for purposes of comparison of performance under closely comparable conditions.

RESULTS.—Duplicate sets of plywood panels were prepared containing 200 mg. per sq. ft. of each test insecticide. Four replications were made with each insecticide, using each set of panels twice, 3 and 4 days after each application of the insecticide.

Of those insecticides tested, pyrethrum, benzene hexachloride (30-per cent gamma isomer content), and DDT showed the most rapid knockdown action in the the order mentioned (Fig. 2). Comparisons were made between DDT and two compounds with substitutions in the p-chloro position, namely methoxychlor and 1, 1 bis-(p-fluorophenyl)-2,2,2 trichloroethane (DFDT). Both of these compounds showed slower knockdown than did the DDT (Fig. 3).

Comparisons were made between DDT and two compounds having substitutions in other parts of the molecule, namely 1,1

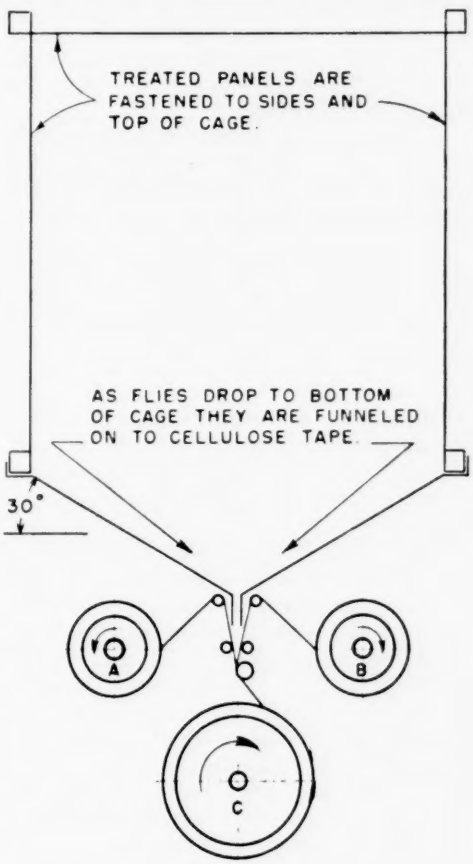
TREATED PANELS ARE FASTENED TO SIDES AND TOP OF CAGE.
AS FLIES DROP TO BOTTOM OF CAGE THEY ARE FUNNELED ON TO CELLULOSE TAPE.
30°
A
B
C

FIG. 1.—Diagrammatic sketch of insect knockdown recorder showing general operation and recorder speeds.

bis-(p-ethoxyphenyl)-2,2 dichloroethane (Q-137), and 1,1 bis-(p-chlorophenyl)-2,2 dichloroethane (TDE). The "Q-137" was between the methoxychlor and DFDT in speed of knockdown reaction while the TDE showed very slow activity (Fig. 4).

Maintaining DDT as a standard, tests with aldrin, heptachlor and chlordane showed progressively slower knockdown (Fig. 5). Finally, tests with dieldrin and toxaphene showed the former to be intermediate between aldrin and heptachlor in activity, while toxaphene had the slowest knockdown activity (Fig. 6).

The lines shown in the figures represent the average results from the four replicates. Fluctuations between replicates were very limited except in the cases of the slower acting insecticides such as chlordane, TDE, and toxaphene. With these insecticides, differences of as high as 20 minutes to attain a given degree of knockdown were encountered.

DISCUSSION.—As an investigational tool, the knockdown recorder has the following advantages:

a. Only knocked-down flies are caught on the tape. Control runs using untreated panels showed only six flies caught on the tape during a 3-hour test run. The V-shaped compartment is entirely dark and offers no light attraction to flies. Food and water are available elsewhere in the cage. Active flies are able to contact the tape and leave it at will.

b. A minimum amount of operator time is required. With the fast-acting insecticides, it was necessary to run the recorder at high speed, 16 feet of tape per hour, and to mark the time every 10 minutes for easy subsequent subdivision into time units. At the slow speed (3 feet per hour) it is possible to obtain readings

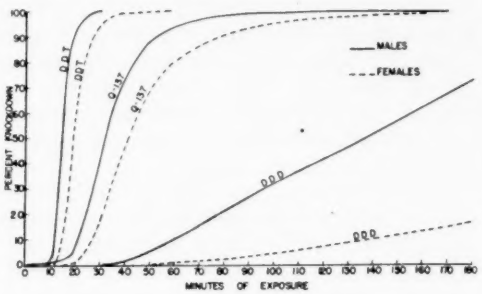

FIG. 4

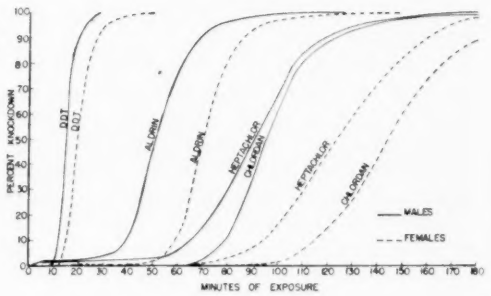

FIG. 5

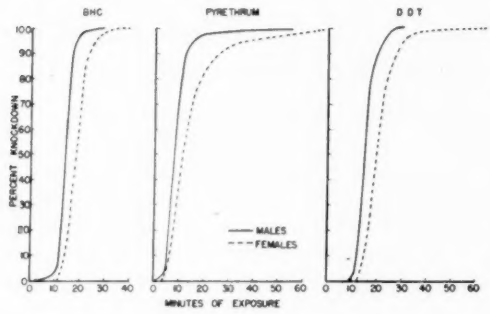

FIG. 2

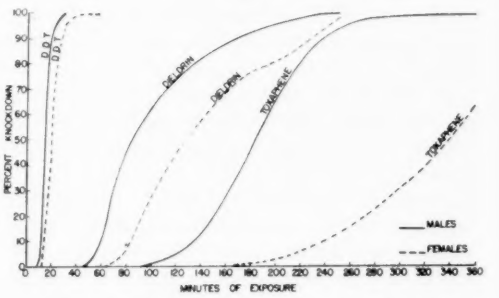

FIG. 6

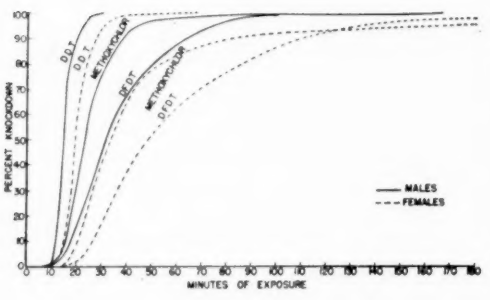

FIG. 3

FIGS. 2–6.—Cumulative per cent knockdown of adult male and female *Musca domestica* with continuous exposure to deposits of 200 mg. per sq. ft. of various insecticides. Observations at 1-minute intervals coincide with recorded lines.

over a 48-hour period without renewing the tapes and it is necessary to mark the tape only every 2 or 3 hours.

c. Comparable results are obtained in duplicate runs. The average time for prostrate flies to hit the bottom of the cage and move down to the V-shaped compartment was less than 1 minute. Under conditions of controlled temperature and humidity, the cumulative curves for knockdown per unit of time are almost identical except in the cases of the slowest acting insecticides.

d. A continuous record of the knocked-down flies is obtained. The number and sex of the flies may then be determined in as small time units as desired. The tapes do not have to be read immediately but may be stored under refrigeration for a period of several weeks.

The knockdown recorder has the following disadvantage: There is no opportunity for the flies to recover from the knockdown effects. This recovery phenomenon is observed with certain insecticides and also in the case of insecticide-resistant strains of flies.

The present recorder represents only one use of the adhesive cellulose tape as a means of obtaining a continuous record of biological data. With modifications, the principle may be applied to many diverse problems. The principle has been used, for example, in a pollen-collecting device (Stenburg & Hall, 1951). The tape has a high resistance to tearing and will withstand considerable tension. In the present study, trouble with broken tape was encountered only once.

Comparison of the knockdown rates for the two sexes of the house fly indicates certain relationships (Table 1). In all cases, longer exposures were required to produce a given knockdown of the female flies than were needed for the males. Compared at the 50-per cent-knockdown level, the difference in time required for the two sexes increased progressively with the less active insecticides. From 30- to 50-per cent longer exposures were required to effect 50-per cent knockdown of the females than were required for the males. This relationship held for all the insecticides tested except the two slowest acting chemicals, TDE and toxaphene.

In general, the halogenated hydrocarbons related to DDT (Figs. 3 and 4) have a common tendency to produce a limited amount of knockdown in 10 to 30 minutes after the exposure period has begun. In contrast the halogenated hydrocarbons of the aldrin-chlordane group produce limited knockdown only after a period of 30 to 90 minutes (Figs. 5 and 6).

Although the results are not directly comparable in studies on the effect of temperature on knockdown (Hoffman & Lindquist 1949) the chemicals related to DDT showed a negative temperature coefficient of effectiveness while those of the aldrin-chlordane group had positive temperature coefficients. The delayed activity of the latter group in producing knockdown may indicate that the action is arising from fumigation rather than from contact.

Table 1.—Minutes of exposure to residual deposits of 200 mg. per sq. ft. of test insecticides necessary to produce 50-per cent mortality of each sex of *Musca domestica*. The difference between exposures for females and males and the proportional increase necessary for females are shown also.

Insecticide	Minutes for 50% Knockdown		Difference	Per Cent Increase ♀/♂
	Males	Females		
Pyrethrum	7.5	11.0	3.5	46
Benzene hexachloride	13.5	18.0	4.5	33
DDT	14.5	19.5	5.0	34
Methoxychlor	23.0	33.5	10.5	45
"Q-137"	32.0	41.5	9.5	30
DFDT	31.5	48.5	17.0	54
Aldrin	51.0	70.0	19.0	37
Dieldrin	85.0	128.0	43.0	50
Heptachlor	91.0	124.0	33.0	36
Chlordane	95.0	144.0	49.0	51
TDE	137.0	299.0	162.0	118
Toxaphene	184.0	340.0	156.0	85

Work with mosquitoes (Yates 1950) showed certain differences between the knockdown efficiency of the various insecticides as compared to the present results with the house fly. Pyrethrum, benzene hexachloride and DDT showed rapid knockdown of both mosquitoes and flies. The DFDT, however, was rated as faster than benzene hexachloride and DDT against mosquitoes but was slower than either compound against the house fly. Methoxychlor was comparatively more effective against the house fly than it was against mosquitoes. TDE and chlordane were superior to aldrin and heptachlor against mosquitoes but not against flies. Aldrin, heptachlor, dieldrin, and toxaphene showed relatively slow knockdown activity against both flies and mosquitoes.

SUMMARY.—A mechanical tape recorder has been developed for securing a continuous record of house flies knocked down by residual deposits of various insecticides. The rate of knockdown for each sex can be obtained by inspection of the tapes at the end of the exposure period or the tapes may be stored for later review.

Comparisons were made of the knockdown effectiveness of 200 mg. per sq. ft. residual deposits of various insecticides. Pyrethrum, benzene hexachloride, DDT, methoxychlor, "Q-137," DFDT, aldrin, dieldrin, heptachlor, TDE, and toxaphene showed a progressive decrease in knockdown activity in the order mentioned.

Differences between the time required for a given knockdown of adult female flies and of male flies showed progressive increase with the slower acting insecticides.

Chemicals related to DDT showed the first knockdown effectiveness in 10 to 30 minutes; those related to aldrin and chlordane showed the first effectiveness in 30 to 90 minutes.

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Evaluation of Acaricides Against Three Species of Orchard Mites[1]

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The European red mite *Paratetranychus pilosus* (C. & F.), and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, are the two principal mite pests of New York apple orchards. Occasionally, light infestations of the clover mite, *Bryobia praetiosa* Koch, are encountered in commercial orchards, but this species is uncommon except in abandoned plantings. The four-spotted spider mite, *Septanychus canadensis* McGregor, has been observed widely within the state. In all cases except one it has occurred in close association with either the European red mite or two-spotted spider mite. The present paper reports control experiments on the first three mite species named.

PRE- AND POST-BLOOM TREATMENTS AGAINST THE EUROPEAN RED MITE.—In an earlier paper, Lienk & Chapman (1951) reported the results that were obtained with tetraethyl pyrophosphate when applied as pre- and post-bloom sprays. In those tests, no difference in control was obtained whether the material was applied in the pink or calyx stages. In both instances control was excellent and equal to or better than with the recommended 2 per cent petroleum oil spray applied in the delayed dormant stage. Because of these results, tests were continued in 1951 and eight acaricides were tested. These materials were applied as single sprays both in the pink and calyx stages; one plat received tetraethyl pyrophosphate at both times. The results of these tests are shown in table 1.

With the exception of the systemic material, tri-alkyl thiophosphate—which was as efficient as a delayed dormant, pink or calyx application—all other materials were more effective as pink sprays. The reason for the difference between the two seasons can be explained on the basis of mite development. Under local conditions, mite and host development are not closely synchronized. Considerable variation exists between seasons. Thus, in 1950, about 50 per cent of the overwintering eggs of the European red

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[2] Mr. Myburgh is a member of the staff of the Western Province Fruit Research Station at Stellenbosch, South Africa. During a year's leave of absence, he spent the summer months of 1951 at Geneva.

Table 1.—Efficiency of several acaricides against the winter eggs and first brood larvae of the European red mite. Host: Rhode Island Greening apple. White Springs Farm, Geneva, N. Y., 1951.

Material and Formulation	Rate per 100 Gals.	Date(s) Sprayed[1]	Number Hatched Mites per Leaf							
			6/20	7/9	7/18	7/25	8/1	8/7	8/15	9/24
Petroleum oil[2]	2 gals.	4/30	0.04	0.1	0.2	0.8	2.7	4.5	8.2	3.4
Petroleum oil	2 gals.	4/30								
TEPP (20% liq.)	4 fl. oz.	6/15, 7/6[9]	0.08	0.0	0.3	0.08	0.2	0.8	2.3	1.2
Tri alkyl thiophosphate (32% liq.)[3]	8 fl. oz.	4/30	0.3	0.04	0.04	0.2	0.8	2.6	1.0	7.5
TEPP (20% liq.)	8 fl. oz.	5/12	0.08	12.0	7.2	5.0	30.8	29.6	30.4	9.7
TEPP (20% liq.)	8 fl. oz.	5/12, 5/24	0	0.2	0.2	1.1	2.7	3.5	9.3	3.1
Parathion (15% w.p.)	16 oz.	5/12	—	0.3	0.8	0.2	2.7	2.6	5.7	6.0
Ethyl-p-nitrophenyl thionobenzene-phosphonate (25% w.p.)[4]	8 oz.	5/12	0.2	0.1	0.08	0.4	1.2	3.3	4.3	2.5
Diethyl-p-nitrophenyl thiophosphate (50% emul.)[5]	8 fl. oz.	5/12	0.4	12.0	20.5	25.9	74.2	57.6	70.2	6.5
2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (15% w.p.)[6]	24 oz.	5/12	0.5	7.1	8.2	12.0	33.2	40.0	49.4	1.2
Di-(p-chlorophenyl) methyl carbinol (25% liq.)[7]	16 fl. oz.	5/12	0.2	0.4	0.1	1.0	4.7	4.1	4.1	2.9
P-chlorophenyl p-chlorobenzene sulfonate (50% w.p.)[8]	24 oz.	5/12	0	0.1	0.1	0.9	4.5	4.3	6.1	2.3
Tri alkyl thiophosphate (32% liq.)[3]	8 fl. oz.	5/12	0.2	0	0.2	0.2	0.2	0.3	1.2	6.0
TEPP (20% liq.)	8 fl. oz.	5/24	0.2	5.3	8.0	47.0	67.2	41.6	57.1	3.6
Parathion (15% w.p.)	16 oz.	5/24	0.4	4.3	5.4	14.8	44.0	27.3	50.6	1.2
2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (15% w.p.)[6]	24 oz.	5.24	0.5	7.4	6.7	28.8	70.8	31.5	39.2	2.6
P-chlorophenyl p-chlorobenzene sulfonate (50% w.p.)[8]	24 oz.	5/24	0.4	0.2	5.0	2.0	11.0	15.8	29.1	5.4
Tri alkyl thiophosphate (32% liq.)[3]	8 fl. oz.	5/24	0.2	0	0	0.4	0.6	1.0	0.4	4.0
P-chlorophenyl p-chlorobenzene sulfonate (50% w.p.)[8]	8 oz.	6/15, 7/6[9]	4.0	0	0.1	0.08	5.7	4.3	11.4	6.8
TEPP (20% liq.)	4 fl. oz.	6/15, 7/6[9]	2.4	0.3	1.5	1.0	5.9	10.2	7.9	2.4
Controls:			13	66	57	87	167	93	46	4

[1] Bud stages on treatment dates were: 4/30 delayed dormant; 5/12 pink; 5/24 calyx.
[2] A "superior" type dormant tree spray oil. For specifications see JOUR. ECON. ENT. 42: 45, 1949.
[3] Systox. Geary Chemical Corporation.
[4] EPN 300. E. I. du Pont de Nemours and Company, Inc.
[5] Metacide. Geary Chemical Corporation.
[6] Aramite. Naugatuck Chemical Division.
[7] Dimite. Sherwin Williams Company.
[8] Ovotran. Dow Chemical Company.
[9] First and second cover sprays.

mite had hatched prior to blossoming. By the end of bloom, virtually all eggs had hatched, and the few females present at this time had not yet started to deposit eggs for the first summer generation. In 1951, however, hatching of the winter eggs occurred earlier in relation to the host, for by the end of bloom a considerable number of next generation eggs had already been laid. The occurrence of such variations point up a fundamental weakness of control programs based on materials like tetraethyl pyrophosphate which possess short residual action. The authors are of the opinion that if early season control is attempted with tetraethyl pyrophosphate or similar acaricides, two sprays should be used. This practice gave excellent results in both 1950 and 1951.

Attention is called to the results obtained, shown in table 1, with single pink and calyx applications of parathion, ethyl-p-nitrophenyl thionobenzene phosphonate, and P-chlorophenyl p-chlorobenzene sulfonate. Because of their more persistent action, some of these may have an advantage over tetraethyl pyrophosphate for use at this season.

In an earlier experiment against the two-spotted spider mite, Lienk & Chapman (1951) found that the systemic material, tri-alkyl thiophosphate, when applied to the orchard ground cover, not only controlled the mites here but the material apparently was also taken up by the tree. This product was used against the European red mite on May 29 in 1951, as a late calyx application. The

Table 2.—Small scale experiment with the systemic material, tri alkyl thiophosphate (32%),[1] used at the rate of 8 fl. oz. per 100 gallons on May 29. Host: Macoun apple. Waterport, N. Y., 1951.

Plot No.	Treatment Applied to	Number Hatched Mites per Leaf					
		6.14	6.26	7.11	7.23	8.8	8.20
1	Entire tree	2.8	0.1	0.2	0.2	1.0	1.7
2	Ground only	19.3	9.9	63.9	17.5	26.5	10.7
3	½ tree	3.5	0.1	0.3	0.8	1.4	5.5
	½ tree unsprayed	31.8	7.2	28.2	15.8	21.9	19.4
4	Control	38.2	22.8	77.1	13.7	20.0	10.2

[1] Systox. Geary Chemical Corporation.

Table 3.—Efficiency of several acaricides against a summer population of the European red mite. Host: Rhode Island Greening apple. North Rose, N. Y., 1951.

Material and Formulation	Rate per 100 Gals.	Per Cent Reduction in Population		
		Days After July 3 Sprays		
		3	10	16
Parathion (15% w.p.)	16 oz.	87.5	95.7	92.9
P-chlorophenyl p-chlorobenzene sulfonate (50% w.p.)[1]	24 oz.	87.5	98.5	98.8
S-(1, 2-dicarbethoxyethyl)-0, 0-dimethyl dithiophosphate (50% emul.)[2]	12 fl. oz.	95.8	97.1	82.9
S-(1, 2-dicarbethoxyethyl)-0, 0-dimethyl dithiophosphate (25% w.p.)[2]	32 oz.	91.6	98.5	88.2
Ethyl-p-nitrophenyl thionobenzene-phosphonate (25% w.p.)[3]	8 oz.	96.0	99.7	99.4
2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (15% w.p.)[4]	24 oz.	54.1	57.1	82.3
2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (50% emul.)[4]	6 fl. oz.	66.6	74.2	89.4
Di-(*p*-chlorophenyl) methyl carbinol (25% liq.)[5]	16 fl. oz.	79.1	71.4	67
2, 4-dichlorophenyl benzene sulfonate (50% emul.)[6]	24 fl. oz.	91.6	98.8	98.2
Diethyl-p-nitrophenyl thiophosphate (50% emul.)[7]	16 fl. oz.	87.5	92.8	95.2
Diothoxy thiophosphoric ester of 7-methyl-4-hydroxy coumarin (32% emul.)[8]	12 fl. oz.	50.0	17.1	0
Tri alkyl thiophosphate (32% liq.)[9]	8 fl. oz.	96.0	99.7	100
2 heptadecyl glyoxalidine acetate (34% liq.)[10]	32 fl. oz.	83.3	91.5	78.8
		Average No. mites per leaf		
Controls:		24	70	17

[1] Ovotran. Dow Chemical Company.
[2] No. 4049. American Cyanamid Company.
[3] EPN 300. E. I. du Pont de Nemours and Company, Inc.
[4] Aramite. Naugatuck Chemical Division.
[5] Dimite. Sherwin Williams Company.
[6] No. 923. General Chemical Company.
[7] Metacide. Geary Chemical Corporation.
[8] Potasan. Geary Chemical Corporation.
[9] Systox. Geary Chemical Corporation.
[10] Crag. Carbide and Carbon Chemical Corporation.

Macoun apple trees used in this experiment were small (12 years old) and required only 8 gallons of spray for thorough coverage. In plats which received the ground cover treatment only, the same amount of spray mixture was used. This ground cover treatment had little or no effect on the mite population level in the tree as is shown in table 2. In a companion series in which only one-half of the tree was sprayed, virtually complete control was attained in the sprayed portion throughout the growing season. Mites on the unsprayed portion remained at a high level, although numbers were somewhat lower than in entirely untreated trees. It is interesting to note that in the

Table 4.—Effect of activated carbon and hydrated lime on the efficiency of parathion (15% w.p.) against the European red mite. Host: Rhode Island Greening apple. North Rose, N. Y., 1951.

Materials and Amount per 100 Gallons	Per Cent Reduction in Population	
	Days After July 3 Treatment	
	3	10
Parathion 1 lb.	87.5	95.7
Parathion 1 lb. & hydrated lime 3 lbs.	75.0	97.1
Parathion 1 lb. & activated carbon ½ lb.[1]	75.0	98.5
Parathion 1 lb. & activated carbon 1 lb.[1]	58.3	97.1
	Average No. hatched mites/leaf	
Controls:	24	70

[1] Nucher C115N. West Virginia Pulp and Paper Company.

Table 5.—Efficiency of TDE and parathion against the two-spotted spider mite. Host: Rhode Island Greening apple. Sodus, N. Y., 1951.

Material and Formulation	Rate per 100 Gals.	Reduction in Population
		9 Days After Treatment
TDE (50% w.p.)	1 lb.	80%
TDE (50% w.p.)	2 lbs.	81
TDE (50% w.p.)	3 lbs.	85
Parathion (15% w.p.)	2 lbs.	99
		Average No. mites per leaf
Control		21

Table 6.—Efficiency of several acaricides against the two-spotted spider mite. Host: Wealthy apple. Sodus, N. Y., 1951.

Material and Formulation	Rate per 100 Gals.	Date(s) Sprayed	Per Cent Reduction in Population			
			Days After First Treatment			
			2	9	20–21	36
Parathion (15% w.p.)	16 oz.	8/7	96.7	96.1	79.0	95.4
	16 oz.	8/7, 8/16	96.7	96.1	96.9	98.4
Ethyl-p-nitrophenyl thionobenzene-phosphonate (25% w.p.)[1]	8 oz.	8/7	93.4	99.5	93.3	97.7
	8 oz.	8/7, 8/16	93.4	99.5	99.6	99.7
P-chlorophenyl phenylsulfone (40% w.p.)[2]	48 oz.	8/7	89.5	98.2	96.9	98.9
	48 oz.	8/7, 8/16	89.5	98.2	99.8	99.5
P-chlorophenyl p-chlorobenzene-sulfonate (50% w.p.)[3]	16 oz.	8/7	79.6	97.3	95.2	97.3
	16 oz.	8/7, 8/16	79.6	97.3	97.9	98.9
2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (50% emul.)[4]	6 fl. oz.	8/7	95.4	99.1	94.9	95.6
	6 fl. oz.	8/7, 8/16	95.4	99.1	99.4	99.5
2, 4-dichlorophenyl benzene sulfonate (50% emul.)[5]	24 fl. oz.	8/7	95.6	96.4	65.8	—
	24 fl. oz.	8/7, 8/16	95.6	96.4	92.5	—
S-(1, 2-dicarbethoxyethyl)-0, 0-dimethyl dithiophosphate (50% emul.)[6]	12 fl. oz.	8/7	97.4	95.0	76.0	36.0
	12 fl. oz.	8/7, 8/16	97.4	95.0	92.1	93.0
Tri alkyl thiophosphate (32% liq.)[7]	6 fl. oz.	8/7	96.4	99.9	100	99.9
	6 fl. oz.	8/7, 8/16	96.4	99.9	99.7	99.7
2 heptadecyl glyoxalidine acetate (34% liq.)[8]	32 fl. oz.	8/7	38.3	—	—	—
Ethoxymethyl-di-(p-chlorophenyl) carbinol (25% emul.)[9]	8 fl. oz.	8/7	92.4	92.4	47.9	34.4
	8 fl. oz.	8/7, 8/16	92.4	92.4	85.6	95.1
	16 fl. oz.	8/7	92.0	95.6	81.4	92.7
	16 fl. oz.	8/7, 8/16	92.0	95.6	95.2	98.6
4, 4'-dichlorobenzilicacidethyl ester-(25% emul.)[10]	8 fl. oz.	8/7	94.1	98.8	87.1	97.1
	8 fl. oz.	8/7, 8/16	94.1	98.8	97.3	98.9
	16 fl. oz.	8/7	94.9	99.6	91.3	98.4
	16 fl. oz.	8/7, 8/16	94.9	99.6	98.5	99.1
(α-(3, 4-dichlorophenyl)-B, B, B-trichloroethyl)-B'methoxyethyl)-carbonate (25% emul.)[11]	8 fl. oz.	8/7	78.7	82.3	0	—
	8 fl. oz.	8/7, 8/16	78.7	82.3	27.5	—
	16 fl. oz.	8/7	76.0	81.7	0	—
	16 fl. oz.	8/7, 8/16	76.0	81.7	47.9	—
			Average No. mites per leaf			
Controls:			59	162	33	46

[1] EPN 300. E. I. du Pont de Nemours and Company, Inc.
[2] R-242. Stauffer Chemical Company.
[3] Ovotran. Dow Chemical Company.
[4] Aramite. Naugatuck Chemical Division.
[5] No. 923. General Chemical Company.
[6] No. 4049. American Cyanamid Company.
[7] Systox. Geary Chemical Corporation.
[8] Crag. Carbide and Carbon Chemical Corporation.
[9] No. 337. Geigy Company, Inc.
[10] No. 338. Geigy Company, Inc.
[11] No. 339. Geigy Company, Inc.

50 per cent sprayed trees the mites did not eventually reestablish themselves in the sprayed portion. The persistence of the systemic material is believed to have been responsible for this result.

SUMMER TESTS.—Eleven materials and various formulations of these were evaluated as single sprays against summer European red mite infestations. Against the two-spotted spider mite, 13 materials were tested both as single and dual applications. The experimental procedure and technique were the same as described in an earlier paper, Chapman & Lienk (1950).

Table 3 shows the data obtained in the test against the European red mite. The mite population in this Rhode Island Greening apple block declined rapidly after the 10-day period, lessening

Table 7.—Efficiency of several acaricides against the clover mite. Host: Apple. Sodus, N. Y., 1951.

Material and Formulation	Rate per 100 Gals.	Per Cent Reduction in Population		
		Days After Treatment		
		3	9	24
Parathion (15% w.p.)	16 oz.	90.6	88.1	71.6
Ethyl-p-nitrophenyl thionobenzene-phosphonate (25% w.p.)[1]	8 oz.	79.5	69.5	57.2
P-chlorophenyl p-chlorobenzene-sulfonate (50% w.p.)[2]	24 oz.	88.3	98.0	100
Tri alkyl thiophosphate (32% liq.)[3]	8 fl. oz.	98.8	98.0	100
		Average No. mites per 12 spurs		
Controls:		181	151	180

[1] EPN 300. E. I. du Pont de Nemours and Company, Inc.
[2] Ovotran. Dow Chemical Company.
[3] Systox. Geary Chemical Corporation.

the usefulness of the 16-day record. Ethyl-p-nitrophenyl thionobenzene-phosphonate, as in all of our earlier tests against this mite, proved more effective than the parathion sprays at the concentrations used. The fruit fungicide, 2 heptadecyl glyoxalidine acetate, has been reported to have some value as an acaricide. It was included in these tests, and as will be seen, the results obtained substantiate the manufacturer's claim. It should be pointed out that hydrated lime was not included with 2 heptadecyl glyoxalidine acetate as is recommended. The slight leaf injury found in this plat may be attributed to this omission.

Activated carbon is suggested as an injury corrective when parathion is used on such varieties as McIntosh and Cortland (Glass 1950). A small scale test was included in the same Rhode Island Greening block referred to above to determine if carbon or hydrated lime impair the acaricidal effectiveness of parathion. Results of this test are given in table 4. Although the inclusion of the charcoal and lime reduced the immediate toxicity of the parathion (see 2-day count), the effect is short lived. For, at the end of 10 days, all treatments were found to be equally effective.

DDT has been "incriminated" as being at least partially responsible for the increased importance of mites in orchard plantings. However, this material and other chlorinated hydrocarbons have also been suspected of having some acaricidal value. In New York, applications of TDE are often made in mid-August for the control of the red-banded leaf roller. Peak activity of the two-spotted spider mite also usually occurs at about this time. Observations made following growers' applications of TDE have frequently shown an appreciable decline in the mite population. To obtain some direct information on how effective an acaricide TDE is, Rhode Island Greening trees were sprayed with various concentrations using a high pressure orchard sprayer. These sprays were put on 1 week following the grower's application of 2 pounds of the same material to the experimental block in which a Speed Sprayer was involved. The pertinent data of this test are shown in table 5. It is quite evident from this record that TDE exhibits some acaricidal action. These data are in line with general observations made in other experimental blocks.

Results of the tests against the two-spotted spider mite are given in table 6. A mature apple orchard of the Wealthy variety was used for this experiment. The experimental technique employed was the same as used in the European red mite test except that on the same day the nine-day record was taken half of the trees in each plat received a second application. Particular attention is called to the check. In this area the population of this species should remain at a relatively high level through August, gradually tapering off in late September. This population pattern has been portrayed graphically by Chapman & Lienk (1950). The mite level in the 1951 experimental orchard dropped unexpectedly sometime between the 9- and 20-day count. It was during this period that the grower applied

TDE to control the red-banded leaf roller. On the basis of tests reported above (Table 5), the writers believe the sudden drop in the check population can be ascribed to the TDE.

The fruit fungicide, 2 heptadecyl glyoxalidine acetate, used with the recommended amount of hydrated lime against the two-spotted spider mite gave only a slight initial mite reduction. After 9 days no apparent control was observed, and further counts were not made in this plat. The difference in performance of 2 heptadecyl glyoxalidine acetate between the European red mite and two-spotted spider mite was reversed in the case of 2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite. Thus, this latter material, which gave mediocre results against the European red mite, gave excellent control of the two-spotted spider mite. Similar results were also obtained during the 1950 season with 2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite (Lienk & Chapman 1951).

P-chlorophenyl p-chlorobenzene sulfonate was used at a one pound level and proved as efficient as at the 1.5 pound rate, which was the dosage employed in previous years.

Another experimental acaricide, 2, 4-dichlorophenyl benzene sulfonate, gave a high kill of both European red mite and two-spotted spider mite in 1951 experiments. In tests against the latter species, however, some leaf drop occurred, and the fruits became spotted and acquired a strong chemical taste. This situation developed where only one application of the material was made. Both fruit injury and leaf drop were accentuated where two sprays were applied.

The clover mite, as mentioned earlier, although normally of only minor importance in well sprayed orchards in this area occasionally attains economic numbers. During 1951 a uniform infestation of this species was located in an abandoned apple orchard. Four materials were tested against this clover mite infestation, and the results are shown in table 7. As will be noted, the basic experimental unit in these counts was a fruit spur. It was found necessary to examine not only the leaves, but also the wood immediately adjoining the leaves because the mites occur in both places. A fruit spur with attached leaves was found to be a convenient sample unit.

SUMMARY.—Control experiments are reported on three species of orchard mites, namely, the European red mite, *Paratetranychus pilosus* (C. & F.); the two-spotted spider mite, *Tetranychus bimaculatus* Harvey; and the clover mite, *Bryobia praetiosa* Koch. One series of tests involved the use of materials directed against the overwintering eggs of the European red mite and the first brood of this species. All pre-blossom (pink) treatments proved more efficient than calyx applications, particularly where tetraethyl pyrophosphate was used. The systemic material, tri alkyl thiophosphate, gave excellent results in single sprays applied either in the delayed dormant, pink or calyx stages.

In summer tests, 2-(p-*tert*-butylphenoxy) isopropyl 2 chloroethyl sulfite continued to prove more effective at the same toxicant strengths against the two-spotted spider mite than the European red mite. A reversal of this apparent specificity was shown for the fungicide, 2 heptadecyl glyoxalidine acetate.

Excellent to good control was obtained against the European red mite and two-spotted spider mite with parathion, ethyl-p-nitrophenyl thionobenzene-phosphonate, tri-alkyl thiophosphate, p-chlorophenyl p-chlorobenzene sulfonate, 2,4-dichlorophenyl benzene sulfonate, S-(1,2-dicarbethoxyethyl)-0,0-dimethyl dithiophosphate, and in the case of the two-spotted spider mite with 4,4-dichlorobenzilicacid-ethyl ester. The experimental material, 2,4-dichlorophenyl benzene sulfonate, caused leaf and fruit injury.

Against the clover mite ethyl-p-nitrophenyl thionobenzene-phosphonate proved inferior to parathion at approximately equal toxicant strengths.

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Further Advances in Alfalfa Snout Beetle Control

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The alfalfa snout beetle, *Brachyrhinus ligustici* L. is a wingless, parthenogenetic weevil infesting alfalfa, red clover, sweet clover and other legumes in the Old World. It is particularly destructive of alfalfa, a favorite host, since the larvae feed on the tap root and the adults feed on the leaves of that plant. The alfalfa snout beetle can and often does destroy a planting of alfalfa in a single generation of 2 years. Fortunately the infestation of the snout beetle in the Western Hemisphere is limited to 4000 acres of northern New York, its spread being limited by the wingless condition of the adults and an extensive yearly baiting program conducted by the Department of Agriculture and Markets of New York.

Previous workers, (Palm 1935; Lincoln 1942; Lincoln & Palm 1941) have studied the biology and ecology of this pest and have established a workable baiting program using a sodium fluosilicate-peanut shell bait. While poison baits on freshly plowed alfalfa sod have given excellent kills of the beetles, the use of sodium fluosilicate baits on growing fields of alfalfa have left much to be desired since the beetles prefer the natural food to that of the baits. A program was initiated in 1947 by Gyrisco *et al.* (1949) to find a suitable substitute for sodium fluosilicate baits on growing fields of alfalfa. They found that parathion, chlordane, benzene hexachloride and toxaphene were all very promising for alfalfa snout beetle control. Further studies on the control of the alfalfa snout beetle using these and several other chlorinated hydrocarbons and organophosphorous insecticides were continued by the authors during the past 3 years.

Methods and Materials.—Tests during 1949 were limited to a comparison of toxaphene, benzene hexachloride and dieldrin in one experiment as thermal aerosols, or to be more nearly correct, as mists and to a comparison of dieldrin, aldrin, chlordane, benzene hexachloride, toxaphene and parathion in another trial as dusts.

The aerosols were made from proprietary emulsifiable concentrates of the toxicants diluted with a commercial oil solvent[2] to make 1 per cent solutions. These solutions were applied by means of a commercial type thermal aerosol machine, at its largest particle size setting, to large unreplicated blocks measuring one-half acre in size. Dosages were calculated for each material on the basis of the weight of the solution and toxicant and repeated runs at 10 feet widths were made over the plots, with the thermal aerosol machine mounted on a pick-up truck, until all of the doses for each treatment had been applied. Some of the aerosol was lost by drift, and it was not possible to gauge accurately the actual amount of toxicant applied to the plots. Hence, the actual amount of toxicant applied can only be approximated.

All of the dusts used in 1949 were proprietary formulations and were calculated and weighed out for each plot at the rate of 1.25 pounds per acre of actual toxicant except for toxaphene which was used at double this dosage since it had proven inferior in 1948 (Gyrisco *et al.* 1949) to some of the other materials tested. The dust plots which were 20 by 40 feet in size were randomized in blocks and replicated 2 times. All of the dusts were applied with a hand fertilizer spreader and were compared with the standard sodium fluosilicate-peanut shell bait which was applied by hand at the rate of 3 bushels per acre.

Effectiveness of the various materials was measured by insect counts taken in several locations at several intervals up to 11 days in each plot. See tables. Wherever possible at least four separate counts of 25 dead or living beetles were made in random areas for each treatment, but in many cases fewer beetles could be counted since infestations in some of the treated plots were very light or were destroyed by birds before counting. Birds, especially seagulls, devour the dead and dying beetles so that an accurate count of the dead beetles cannot always be made. All the data for the two experiments in 1949 are presented in tables 1 and 2.

[1] The authors acknowledge the assistance of R. H. Burrage in part of this work.
[2] Shell Horticultural Oil Number 7.

Table 1.—A comparison of several organic insecticides in oil solutions and water suspensions applied at the rate of approximately 1.5 pounds of actual toxicant per acre with a commercial thermal aerosol machine.[1] Belleville, Jefferson County, New York. 1949–50.[2]

TREATMENT	DATE	PER CENT REDUCTION AT—DAYS						
		3	4	5	6	7	8	9
Oil Solutions								
	1949							
Benzene hexachloride	April 30	100	99	—	—	77	—	98
Toxaphene	April 30	73	97	—	—	46	—	95
Dieldrin	April 30	—	27	—	—	—	—	73
	1950							
Benzene hexachloride	May 10	—	—	80	—	—	100	—
Dieldrin	May 11	—	100	—	—	98	—	—
Aldrin	May 12	80	—	—	94	—	—	—
Toxaphene	May 12	56	—	—	52	—	—	—
Water Suspensions								
Dieldrin	May 12	88	—	—	96	—	—	—
Aldrin	May 12	86	—	—	82	—	—	—
Chlordane	May 12	86	—	—	72	—	—	—
Benzene hexachloride	May 12	60	—	—	52	—	—	—

[1] *Tifa*, Model 40-E-48, Todd Shipyard Corp. Machine settings: Particle size in microns—60, Fuel pres.—45 pounds, Air pressure—3.25 pounds, Temperature at nozzle—1000° F.
[2] No reduction observed in uneated plots.

Trials during 1950 were somewhat more extensive than during 1949. Dieldrin, aldrin, chlordane and benzene hexachloride were compared as emulsions on May 8, 1950, when applied by means of a truck mounted low pressure-low volume sprayer to large unreplicated field plots measuring 20 by 200 feet in size. Dosages of each emulsion were calculated on a weight basis so that 1.0 pound per acre of actual toxicant would be applied in 5 gallons of water. Several runs were made over each plot until all of the emulsion had been applied as uniformly as possible.

Dieldrin, aldrin, chlordane, lindane and parathion were also applied May 5, 1950, as dusts at the rate of 1.0 pound of actual toxicant per acre to large unreplicated blocks of alfalfa measuring 20 by 200 feet in size. All of the dusts used were commercial 1 per cent impregnated preparations. Each dust was weighed out for each plot and applied with a power forage crop duster mounted on a half-ton truck.

In addition to the spray and dust plots, 2 series of bait plots were laid out on fallow, fall-plowed, alfalfa ground in 1950. Aldrin, dieldrin, and chlordane were substituted for sodium fluosilicate in the standard bait formula at the rates of 1 and 2 pounds each to make up 3 bushels of bait which is applied on one acre. In each case, the baits were compared with sodium fluosilicate which was used as a standard. In one series of bait plots, the baits were mixed and applied immediately, but in another series of plots the baits were mixed, and 1 pint of formalin was added

Table 2.—A comparison of several synthetic organic insecticide dusts with the standard peanut shell bait for control of the alfalfa snout beetle when applied with a hand fertilizer spreader. Belleville, Jefferson County, New York. April 29, 1949.

TREATMENT	ACTUAL TOXICANT LBS./A.	PER CENT REDUCTION AT DAYS				
		4	5	6	9	11
Dieldrin	1.25	50	80	100	100	100
Aldrin	1.25	—	100	100	72	100
Chlordane	1.25	—	—	40	87	100
Benzene hexachloride	1.25	47	50	100	95	97
Parathion	1.25	—	90	100	100	95
Toxaphene	2.50	—	71	100	90	95
Standard Sodium Fluosilicate bait	8.0	—	—	76	86	95

Table 3.—A comparison of several organic insecticides when applied as sprays with a low pressure—low volume sprayer[1] for control of the alfalfa snout beetle. Belleville, Jefferson County, New York. 1950–1951.

Treatments	Actual Toxicant Lbs./A.	Per Cent Reduction 2 Days	4 Days
Applied May 8, 1950			
Dieldrin	1.00	92	100
Chlordane	1.00	87	92
Benzene hexachloride	1.00	60	90
Aldrin	1.00	90	83
		3 Days	5 Days 7 Days
Applied May 9, 1951			
Dieldrin	1.00	70	90 97
Aldrin	1.00	90	80 96
Lindane	1.00	40	50 86
Parathion	1.00	60	70 86

[1] Myers Silver Cloud Weed Sprayer. Pressure: 40 pounds per square inch. Nozzles: 15 fan type, Teejet #650067, mounted on 20 foot boom. Rate of application: 5 gallons per acre at 5 miles per hour.

to the formula to prevent spoilage. The formalin treated baits were allowed to stand for a week to see if such a delay before application would affect their toxicity of the baits or ruin their attractiveness to the beetles. All of the baits were applied on May 6 and May 13 to one-fourth acre plots randomized in blocks and replicated twice.

Effectiveness of the various treatments in all of the experiments was determined by insect counts taken at the intervals

Table 4.—A comparison of several organic insecticides when substituted for sodium fluosilicate in the standard peanut shell baits[1] for control of the alfalfa snout beetle when applied at the rate of 3 bushels per acre. Belleville, Jefferson County, New York. 1950.

Treatments	Actual Toxicant Lbs./A.	Per Cent Reduction at 12 Hours	48 Hours
Untreated baits applied May 6, 1950			
Aldrin	1.0	84	100
Aldrin	2.0	84	100
Dieldrin	1.0	76	98
Dieldrin	2.0	95	100
Chlordane	1.0	76	96
Chlordane	2.0	82	98
Standard sodium fluosilicate bait	8.0	73	97

Treatments	Actual Toxicant Lbs./A.	12 Hours	48 Hours	72 Hours
Formalin-treated baits applied May 13, 1950				
Aldrin	1.0	50	97	99
Aldrin	2.0	61	100	99
Dieldrin	1.0	71	99	99
Dieldrin	2.0	72	99	100
Chlordane	1.0	45	96	100
Chlordane	2.0	49	97	99
Standard sodium fluosilicate bait	8.0	40	88	94

[1] Formula of standard bait: Peanut shells, 85 pounds; sugar, 20 pounds; soy bean flour, 18 pounds; sodium fluosilicate, 8 pounds; formalin, 1 pint; water, 12 gallons to make up 3 bushels of bait.

Table 5.—A comparison of several synthetic organic insecticides when applied as dusts with a power forage duster[1] for control of the alfalfa snout beetle. Belleville, Jefferson County, New York. May 1950–1951.

Treatments	Actual Toxicant Lbs./A.	Per Cent Reduction at 3 Days	5 Days	14 Days
Applied May 5, 1950				
Dieldrin	1.00	80	100	100
Aldrin	1.00	83	86	96
Lindane	1.00	66	83	86
Chlordane	1.00	76	100	83
Parathion	1.00	60	60	70
Untreated	—	0	0	0
		1 Day	3 Days	7 Days
Applied May 3, 1951				
Dieldrin	1.00	70	73	99
Aldrin	1.00	30	96	100
Lindane	1.00	100	83	86
Toxaphene	1.00	37	80	100
Parathion	1.00	73	100	100
Untreated	—	0	0	0

[1] Niagara Model AA "Even-feed" Alfalfa Duster powered with a Model ZZ Briggs and Stratton Engine.

indicated in tables 3, 4 and 5. Twenty-five beetles were examined at four random locations in each treatment and recorded as dead or alive. In some cases 100 beetles could not be found, for reasons previously indicated, and the effectiveness of the treatments had to be based on counts of fewer beetles. Where the counts were too low to be of significance, they have been omitted from the tables.

During 1951 a series of dust and spray treatments similar to those of 1950 were applied in two experiments on May 3 and May 8. All the insecticides were used at the same rate of actual toxicant per acre as in the previous year. However, the plots were somewhat larger in 1951 than in 1950. The dust plots were 20 by 272 feet in size while the spray plots were 20 by 213 feet in size. In each case, the treatments were applied to large unreplicated plots separated by 10-foot untreated guard strips. In the spray experiment in 1950, lindane and parathion were substituted for chlordane and benzene hexachloride while in the dust experiment toxaphene was substituted for chlordane. (Tables 3 and 5). The sprays and dusts were applied with the same machinery and in the same manner as in 1950, which has already been described, except that a tachometer was mounted on the truck to aid in judging the speed of the applicator. By calibrating the power duster and low volume sprayer it was possible to apply the proprietary formulations accurately and evenly without retreating the plots.

Insect counts were made at the intervals indicated in the tables and in a manner as in the previous years.

DISCUSSION.—In the thermal aerosol experiment (Table 1) during 1949 and 1950, the oil solutions of the toxicants were found to be slightly, though not consistently, more effective than water suspensions of the same toxicants at the same rate of toxicant per acre. However, the difference in toxicity was not great enough to warrant the use of expensive oil solvents when water can be used as the diluent for the toxicants. There was little to choose between the various materials tested except that toxaphene and benzene hexachloride as water suspensions were poorer than the other formulations tested. However, benzene hexachloride as an oil solution was equal to dieldrin and aldrin which were consistently best in all of the trials. Chlordane as a water suspension was inferior to water suspensions of aldrin and dieldrin but appeared to be somewhat more effective than a water suspension of benzene hexachloride. The thermal aerosol machine was found to be very mobile under the wet field conditions of northern New York in the spring and was found to be effective for quick spot treatments of small infestations of alfalfa snout beetles even under adverse atmospheric conditions. However, the machine was effective only when used at its largest particle size setting and at distances no greater than 10 to 20 feet from the nozzle. Under these conditions the machine simulated a mist blower since the particles formed were too large to be classified as aerosols but rather as mists.

One might question why the per cent reduction varies from count to count sometimes upward and sometimes downward. The reason for this is that the beetles emerge from the ground over a period of several weeks and during any one day there may be beetles that have just emerged from the ground and are unaffected. As a result these unaffected beetles are counted as live beetles. The counts that give the best indication of the results are those that are taken 7 to 10 days after the application of the insecticides when most of the beetles have emerged from the ground and have been exposed to the insecticides.

In the dust experiments during 1949, 1950, and 1951, dieldrin appeared to be the most effective of all the materials tested over the 3-year period although there was little to choose between the various materials tested. Under the ideal dry conditions of 1951, lindane gave the quickest kills but in 1950 when the weather conditions in the test area were unsettled during the test period, the beetles spent much of the time underneath the duff and the kills were somewhat poorer in the earlier counts. However, at the 5 to 7 day interval after treatment in the both years, the kills were the same. Lindane was poorer than dieldrin but about the same as aldrin which seems to fall somewhere in between. At 1.25 pound per acre dosage when benzene hexachloride was used instead of lindane there appeared to be little to choose between the three materials after 5 days. Parathion, chlordane, and toxaphene all gave good kills although toxaphene was a little slower than the other materials when used at the same rate of toxicant per acre. Parathion for some unknown reason did not perform as well in 1950 as it did in the other 2 years. On the basis of toxicity of the insecticide alone, there is little to choose between the materials. When toxicity to the operator, livestock and to bees, residues, and other points are considered toxaphene, aldrin, and lindane may be superior in some respects to the other materials tested.

In the spray tests during 1950 and 1951, dieldrin again gave the highest kills although there was little to choose between the materials on the basis of their performance for the 2 years. Sprays did not give any faster kills than dusts but drifted less and were less unpleasant for the operator to apply. The low volume sprayer proved to be ideal for use on the wet soils of northern New York because of its light weight and large pay load.

In the bait tests, it was found that dieldrin, aldrin, and chlordane could be substituted for the sodium fluosilicate in the standard alfalfa snout beetle formula. One pound per acre of each of the organic toxicants was found to be highly effective and had a toxicity equal to 2 pounds of the same toxicant but even smaller dosages may possibly be used since 1 pound was the lowest dosage tested. The organic toxicants were found to give not only stomach but also contact action, unlike the standard bait. None of the organic materials

repelled the beetles, and the organic and standard baits were equally accepted. A cursory examination of the baited plots 2 weeks after application indicated that the organic baits were still killing the beetles while the inorganic baits were ineffective indicating that fewer reapplications of the organic baits would probably be needed than with the standard bait where 2 to 3 applications are often made. Adverse weather conditions did not seem to hurt the effectiveness of the organic baits as much as it did the standard inorganic bait.

The use of formalin in the organic baits and the storage of these baits for 1 week did not adversely affect the action of the baits or reduce their attractiveness to the beetles. More work is needed on the minimum concentration of toxicants of the various organic materials to be used in baits for the maximum kills at the minimum costs. Work with other synthetic organic materials is also contemplated.

SUMMARY.—In several field tests in Jefferson County, New York, during the past 3 years dieldrin, aldrin, chlordane, lindane, parathion, toxaphene and benzene hexachloride were evaluated as sprays, dusts and mists for the control of the alfalfa snout beetle. Dieldrin, aldrin, and chlordane were also used in baits and were compared with the standard sodium fluosilicate bait. With all methods of treatment, there appeared to be little to choose between any of the materials on the basis of toxicity to the alfalfa snout beetle alone. Of all the materials tested, dieldrin was slightly, though not significantly, better than the other materials tested while toxaphene was the poorest although it, too, was effective and gave good commercial control.

Mist applications of oil solutions or water suspensions of aldrin, dieldrin, chlordane, toxaphene and benzene hexachloride were found to be effective for spot treatments of small islands of infestations of the snout beetle even when applied under adverse atmospheric conditions.

The use of dieldrin, aldrin and chlordane in the standard alfalfa snout beetle bait showed these materials to be highly effective even at 1 pound per acre dosages. Furthermore the organic baits persisted longer in their toxicity than did the standard bait.

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Some Effects on Insect Control and Plant Response of a Systemic Insecticide Applied as a Spray, a Seed Treatment, or a Soil Treatment[1]

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Insecticides which are absorbed and systemically translocated, and which persist insecticidally within treated plants, make possible new approaches to insect control. The use of such materials also implies many effects which such toxicants might exert upon germination, growth and yield characteristics of treated plants.

The work reported here is an attempt to evaluate the effect of a systemic insecticide on germination, growth, insect populations, time of maturity, yields and quality of edible portions of treated crops. Amounts of insecticidal residues in peas were also determined. Peas and eggplants were used in these tests.

[1] The authors wish to express their appreciation to Dr. James E. Webster of the Oklahoma A. and M. Experiment Station, Department of Agricultural Chemistry Research and to Professor Eula Morris of the Department of Household Science Research, for cooperation and for analysis of green peas, and grading and shelling of peas.

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Davish & Apple (1951) report field control of the pea aphid *Macrosiphum pisi* (Kltb.) on peas with octamethyl pyrophosphoramide applied as a foliage spray or as a pre-planting spray on soil. In another field test the above mentioned systemic, a trialkyl thiophosphate, and a trialkyl selenophosphate were applied as sprays made from emulsifiable concentrates. Good aphid control by each, and small residues of the latter mentioned two systemics were reported.

Bronson & Dudley (1951) also reported a series of greenhouse and field tests in which octamethyl pyrophosphoramide and a trialkyl thiophosphate were applied as a foliage spray, or a solution poured on the soil, or as a diluted or undiluted solution poured on the seed. Gum arabic was used by these workers to insure higher deposits for one treatment.

Chao (1950), and Ivy *et al.*, (1950), and Ripper *et al.* (1950), also reported successful control of aphids by seed treatments or other methods involving translocation of systemic insecticides.

METHODS AND MATERIALS.—Peas of the variety "Little Marvel" were used as a test crop. Three methods of application of the toxicant—a foliage spray, a seed treatment, and a soil treatment were employed. Application by these methods and a combination seed-plus-foliage spray, and an untreated check constituted the five treatments. Four plots of each treatment were used, arranged in a completely randomized design. Individual plots consisted of three 12-foot rows spaced 20 inches apart. Such spacing arrangement was necessary because of the limited area of uniform soil available, but very little evidence of interaction between adjacent plots was noted.

The only toxicant used was a diethoxythiophosphoric acid ester of 2 ethyl mercaptoethanol.[1] In the seed and soil treatments, a 50 per cent-on-activated-charcoal formulation was used; for spray treatments, a dilution from an emulsifiable concentrate containing 32.1 per cent of active ingredient was employed.

A weighed lot of seeds was treated in a jar with a carefully weighed amount of the charcoal formulation. To facilitate adherence of the toxicant, the seeds were first moistened and allowed to stand until the surface of the seed felt only slightly moist. 6.8 grams of the carbon formulation was applied to 1362 grams (dry weight) of pea seeds. This was intended to give a rate of 8 ounces of the charcoal mix per 100 pounds of seed. A seeding rate of 1 pound per 100 row feet was used and lots for individual rows were carefully weighed and packaged.

The soil treatment was arbitarily set at 12 grams of the charcoal formulation per 36 row feet. It was anticipated that this rate would likely be phytotoxic and far above economically feasible levels. The 12-gram lots were placed in a quart mason jar half filled with slightly moistened glass sand. More sand was added above the insecticide, the lid secured and the jar rotated and shaken until a uniform gray indicated the ingredients were thoroughly mixed. In the field, the lid was replaced by a 16 mesh screen cap, the jar inverted so that the sand flowed slowly but freely through the screen to give the uniform band in a 0.66 inch strip in the bottom and sides of a furrow.

The spray made by adding 7.1 cc of the 32.1 per cent concentrate to 8 quarts of water was uniformly applied at a rate of 1 quart to each 36 row-foot plot with a knapsack sprayer. The spray was applied to plots which had received neither soil nor seed application for the check-plus-spray treatment, and to plots receiving the seed treatments for the seed-plus-spray treatment.

In planting the peas, furrows were opened up with a hand plow to a depth of about 2 inches. Seeds were placed in the furrows and the 100 seeds to be used for emergence count were set off by garden labels before the seeds were covered. These emergence counts were made April 6, 32 days after planting, at a time when the plants were about 2 inches high. "Retarded" plants were less than an inch tall and with foliage definitely light colored.

This experimental area lay north of a highly infested 20-acre alfalfa field, and the prevailing southern winds carried high populations of winged pea aphids into and across the experimental area from the time of the first appearance of the pea plants. Formal aphid counts were made by carefully examining the leaf and stem surfaces of five plants on the center row of each plot on April 9, 14, 20 and 27, and May 4.

Heights of the plants, expressed in centimeters, were determined as the distance from the soil level to the growing tip on April 14 and April 27.

Filled pods were harvested on May 23 and May 28. To minimize errors due to judgment of maturity, etc., each row was individually picked and the pods weighed. Total yields were secured for plots of three rows. Samples of peas in the pods were packed with dry ice and sent by air express to Geary Laboratories[1] for residues analysis of shelled peas. A second series of samples were analysed locally for total solids, ash, reducing sugars, sucrose, and total sugars.

The remaining pods of each lot were run through a small commercial pea and bean huller to obtain shelling percentages.

In the second picking, flat pods were common only to the check plots. The peas from the second picking were hulled by hand, and shelling percentages and size grades obtained.

EGGPLANT.—The variety "Black Beauty" was planted in this test. Eggplants are usually subject to severe infestation by three kinds of insect pests; Colorado potato beetles (adults and larvae), flea beetles and lace bugs. It was not anticipated that control of the first two species could be obtained by a systemically-administered toxicant. It was thought that the lace bugs might be controlled by a systemic in that it feeds by sucking piercing mouthparts, although a relatively small amount of sap is ingested by the insect.

Seeds of eggplant were sown in vermiculite in the greenhouse on March 15. Seedlings about 1.5 inches in height, were pricked off into soils in 2 by 2 by 3 inch wood veneer bands. Plants 5 to 8 inches high were transplanted to the field on May 3.

Four levels of the systemic in the soil application (2.5, 1, 0.5 and 0.2 grams per plant of charcoal formulation) and an untreated check constituted the five treatments which were arranged in the field in a completely randomized pattern in three rows of 17 plants each. Guard plants were used at the ends, and nine plots of each treatment were employed. Individual plants spaced 30 by 36 inches were considered as plots inasmuch as toxicant could be confined to the soil immediately under each plant. The systemic insecticide diluted with sand in pint jars as previously described was poured into the hole opened for the transplant and mixed with the resident soil. Veneer bands were carefully removed and the plants set in the soil and watered in with a "starter" solution.

Native solanaceous weeds provided large numbers of Colorado potato beetles, *Leptinotarsa decemlineata* (Say), flea beetles, *Epitrix cucumeris* (Harr.), and *Epitrix fuscula* Crotch, and lace bugs, *Gargaphia solani* (Heid), in the area of the experimental plots. It was necessary to hand-pick adult and larvae potato beetles at 2 to 4 day intervals to prevent excessive plant defoliation. Feeding by flea beetles was observed within 24 hours of the time the plants were set in the plots. It soon became evident that the populations were selecting certain plants, so no attempt was made to control or alter the flea beetle populations. No insecticidal sprays or dusts were applied to the experimental plants after setting. The crop was cultivated as necessary with hand tools and row irrigated on two occasions.

To secure a record of flea beetle damage, images of typical leaves were reproduced on blueprint paper on June 4.

[1] Geary Chemical Co., Bluepoint, Long Island, New York.

Table 1.—The effect of a systemic insecticide applied as a seed, spray, soil, or combination treatment on emergence and growth of peas.

	CHECK	CHECK SEED SPRAY	SEED	SEED AND SPRAY	SOIL	L.S.D. 5%
Emergence percentage	80	83	79	85	83	Not sig.
Retarded percentage	3.7	4.5	3.2	2.2	4.5	Not sig.
Height (inches) April 14	3.6	3.5	3.5	3.2	2.7	0.44
Height (inches) April 27	8.6	12.0	16.0	15.0	15.2	1.68

Table 2.—The mean numbers of aphids found on 5 plants from plots receiving various systemic treatments.

TREATMENT	APRIL				MAY 4	TOTAL
	9	14	20	27		
Check	1237	2038	2318	2595	1820	10,008
Check & Spray	1081	1722	31	6	25	2,865
Seed	2	3	4	4	4	17
Seed & Spray	3	3	2	2	6	16
Soil	2	1	2	1	3	9

Flea beetle damage was identified on the blueprints by comparing a few dried-pressed leaves with their blueprint images until typical injury patterns were recognized. Actual counts of flea beetle punctures were made from the blueprints representing leaves from each plot.

DISCUSSION.—As indicated by the data in table 1, the emergence of peas was not affected by either seed or soil treatments. This per cent emergence, as well as delayed emergence, for plots where the toxicant was applied to the seed ("seed" or "seed-plus-spray") and for plots where the toxicants were applied to the soil (soil) did not significantly differ from that of plots in which no toxicant was present ("check" or "check-plus-spray").

Height measurements on April 14 (40 days after planting) suggest that aphid infestations had little effect, but that the soil treatment had significantly retarded growth. As is shown in table 1, by April 27 a highly significant retardation of growth in the untreated check was found, and a similar but lesser effect in the check-plus-spray plots. It should be noted that the peas in plots of this treatment were sprayed on the same day the first measurements were made, so the increase in growth over the check is a measure of the advantage of the protection from aphids in the intervening 2-week period. It should also be noted that plants on soil treated plots had overcome the growth deficit noted on April 14.

The aphid counts presented in table 2 are remarkable in two respects. First, a very high infestation was present for a long period of time. Second, a very nearly perfect control of aphids was obtained in every plot where the toxicant was applied to the seed or the soil.

The spray application reduced the aphid populations from initially high numbers to relatively few, and it was observed that these few were almost exclusively in small colonies on the lower sides of older leaves near the ground. New plant growth became toxic and remained so for the duration of the counting period.

Without exception, all aphids counted on the seed or soil treated plots were winged females. These did not succeed in reproducing on treated plants. Many dead winged females were found beneath treated plants, suggesting a toxic rather than repellent effect.

Lady bird beetles and aphid lions became increasingly numerous during the counting period, and counts were discontinued May 4 because it was evident that biological control was becoming a major factor in determining the populations. Observations of aphid populations

Table 3.—The effect of a systemic applied as a seed, spray, soil, or combination treatment on yields of peas.

YIELDS (OZ.)	CHECK	CHECK AND SPRAY	SEED	SEED AND SPRAY	SOIL	L.S.D. 5%
First picking	13.5	89	115	124	129	16
Second picking	24	35	29	27	32	Not sig.
Total	37.5	124	144	151	161	18
First percentage of Total in picking	36	72	80	82	80	9

Table 4.—Shelling percentages and size of peas from plots treated by the systemic insecticide.

Treatment	Shelling Per Cent		Size (2nd Pick)	
	Machine	Hand	Large	Small
Check	41	43	43%	57%
Check & Spray	45	44	56	44
Seed	48	43	58	42
Seed & Spray	47	43	61	39
Soil	45	40	65	35

were continued until harvest, however, and the soil-treated plots remained essentially aphid free. Toward harvest time, the "seed" treated, and "seed-plus-spray" treated plants were occasionally infested with small colonies of 2 to 4 young aphids or wingless adults; the "check-plus-spray" treated plots again showed spotted infestations of both young and adult aphids. The populations on check plots were observed to decline somewhat after formal counting was discontinued and the plants responded with renewed but irregular growth.

Yields presented in table 3 showed a consistent increase in direct proportion to the total amount of systemic applied. Highly significant differences separated the mean check yield from those of all treated plots. Plots receiving soil and seed applications yielded significantly more peas than those receiving only the spray treatment. It is of interest to note how uniformly early the peas in the treated plots matured. This is particularly pointed up in the "percentage of total in first picking." A further indication of earliness is given in the size ratings of the second picking listed in Table 4. Here it will be noted that plants receiving the "seed," "soil," and "seed-plus-spray" treatments had a higher percentage of large peas, and it was obvious that some of these should have been harvested in the first rather than the second picking. Smoothness and uniformity of size and and appearance of pods in this group were distinct enough to warrant comment from almost everyone who saw and compared them.

Analyses of solids and sugars also indicated that the soil-treated peas matured first, and those on the check plots last. All samples were of high quality. Toxic residues in the shelled peas were below the threshold of detection except in the soil treated sample where 1.6 ppm were found.

Table 5.—The sugar-solids analysis of green peas from various systemic treated plots, and residues of the analyses in shelled peas.

Treatment	Solids	Ash	Percentages of Green Weight			Systemic Residues
			Red Sugars	Sucrose	Total Sugars	
Check	18.52	0.73	0.32	5.64	5.96	—
Check & Spray	20.37	0.76	0.24	4.55	4.79	0.1
Seed	20.15	0.72	0.20	4.80	5.00	—
Seed & Spray	19.92	0.74	0.22	5.09	5.31	0.1
Soil	19.72	0.72	0.24	4.63	4.87	1.6

Table 6.—Average measurements of plants, insect damage and yields of eggplants treated with four levels of systemic applied to the soil.

Treatment	Plant Measurements		Insect Damage		Weight in Ounces	
	Height (In.)	Weight (Oz.)[1]	Lace Bug 1–5 Index[2]	Flea Beetle Punct. per Leaf	Total	Average per Fruit
Check	16.6	12.1	3.39	252	10.4	5.03
¼ gram	19.3	17.9	3.06	66.0	22.0	8.7
½ gram	18.9	18.1	2.5	17.0	37.8	12.6
1 gram	19.1	21.1	2.2	12.0	31.9	10.1
2½ grams	21.2	22.1	1.1	9	42.8	14.2

[1] Weight of stems and leaves only.
[2] An index rating with 1 as no damage, 5 as very severe damage.

EGG PLANT.—The highest dosage rate (2.5 grams), contrary to expectations, did not produce marked phytotoxicity, although some plant wilting was noted in the first two weeks after transplanting. Height, weight of plant (stem and leaves) yield of fruits (ounces) of eggplants all consistently increased with increased dosage of the toxicant as indicated in table 5. Perhaps these increases can be explained by the insect control. The control of flea beetles is particularly remarkable in that this, to our knowledge, represents the first record of a high degree of control of this group of insects by an organic phosphate systemically administered.

There was considerable variability in the lace bug infestation among plants and among leaves of the same plant, in spite of attempts to introduce this pest. Natural enemies apparently decimated many lace bug colonies. Check plants and those receiving 0.2 gram treatments could be readily separated from others on the basis of both flea beetle and lace bug injury. The only plants showing complete freedom from lace bug injury were those receiving the 2.5 gram treatment. It should be stressed, however, that even the highest level had no apparent affect on either adults or any larval instar of Colorado potato beetle.

The yields were profoundly affected by the treatments, especially in the early pickings. About four times as much fruit was produced on the "2.5 gram" plots as in the check on a weight basis. Even the plants receiving "0.2 gram," which did not adequately protect the plants from either flea beetles or lace bug injury, yielded twice as much fruit as the plants of the untreated check.

SUMMARY AND CONCLUSIONS.—Peas were treated with the systemic, diethoxythiophosphoric acid ester of 2-ethyl mercaptoethanol, applied as a soil, seed, or spray treatment, or a combination seed-plus-spray treatment. A high degree of pea aphid control resulted under conditions of severe infestation. Seed germination as indicated by plant emergence was not influenced, nor was the plant growth permanently affected by the toxicant. Yields increased directly with the insect control obtained. The crop on plots receiving the more efficient treatments mature earlier with pods of superior market quality.

The systemic applied either to the seed or in the soil provided effective control throughout the 80 days between planting and harvesting. Somewhat less effective control was obtained by spraying the same toxicant on the foliage of untreated plants 40 days after seeding.

Residue analyses showed only traces of the toxicant in all but the soil-treated peas which contained 1.6 ppm.

Eggplants grown in soils into which the systemic had been incorporated previous to transplanting were protected from both flea beetles and lace bugs, and yielded 2 to 4 times as much fruit as unprotected plants.

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Mating Experiments with the Two-spotted Spider Mite Complex[1]

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The purpose of the present paper is to clarify the taxonomic status of *Tetranychus multisetis* McGregor. *T. multisetis* is very closely related to *T. bimaculatus* Harvey, and specimens determined under these two names have been cross-mated to investigate their ability to interbreed.

Mating may occur between closely related species of tetranychid mites (McGregor & Newcomer 1928), although fertilization is not known to take place. Fertilized females produce both males and females, whereas unfertilized females produce only males.

COLOR VARIATION.—The two-spotted spider mite, *Tetranychus bimaculatus*, has been reported by a number of authors as being a mite of various colors. Ewing (1914) and Cagle (1949) discussed variations in color of these mites from green to yellow, to orange or brown, but neither author found them to be carmine. McGregor & McDonough (1917), however, considered brick red to be the dominant color of the females of this species in the southeastern United States. Neiswander *et al.* (1950) have recently shown that green and red populations of *T. bimaculatus* were physiologically distinct on the basis of their reaction to acaricides.

In 1950 McGregor described *Tetranychus multisetis*. Specimens referable to this name were previously identified as *T. bimaculatus*. Females of *T. multisetis* are always carmine in color, and they differ from carmine females of *T. bimaculatus* only in possessing additional setae on the fore tibia and tarsus. Davis (1950) showed that *T. multisetis* interbreeds readily with carmine females of *T. bimaculatus*.

In the study reported here males and females of *Tetranychus multisetis* were cross-mated with green individuals of *T. bimaculatus*.

EXPERIMENTAL METHODS.—Yellow sorrel, *Oxalis corniculata* L., was found to be a satisfactory host on which to rear the mites in the laboratory. The plants were obtained from a source free of spider mite infestation.

Host plants were cut to lengths of about 3 inches with two or three leaves. These were placed in individual vials containing tap water, and the openings were plugged with cotton surrounding the plant stems. The upper rims of the vials were bordered with about one-fourth inch of tangle-foot in order to prevent laboratory contamination by wondering mites. However, this method did not prevent mites placed on the plants from leaving, which sometimes occurred. Similar vials of plants were used in progagation of the colonies from which individuals were selected for mating experiments. The cultures lasted two to four weeks depending on the amount of feeding by the mites.

Since the mite population on the host plant increased rapidly after an initial build up, it was necessary to control the population within limits needed. Older plants were discarded, and new plants, on each of which two or three mites were placed, were used to maintain the culture. In addition to keeping the mite population within desired limits this method prevented the dispersal of mites within the laboratory which would have occurred if host plants were allowed to die out completely.

In order to obtain males in sufficient numbers, immature females, usually in the deutonymph stage, were placed on individual plants and allowed to mature and produce eggs without mating.

For the mating experiments nymphs were placed on individual plants and allowed to mature. After the females were mature the plants were examined for any eggs which may have been laid. If eggs were found, they were removed. A male was then transferred to a plant with a female, and mating was observed under a microscope. The male was removed afterwards to prevent the possibility of its mating with the female progeny.

Individual vials of *Oxalis corniculata* were marked with serial numbers. A board with holes drilled at intervals was used to hold the vials, but no contact of

[1] Submitted in partial satisfaction of the requirements for the degree of Master of Science in Entomology in the Graduate Division of the University of California.

Table 1.—A summary of sexes produced by matings of *Tetranychus multisetis* females and *T. bimaculatus* males.

GENERATIONS	NO. ♀♀ ALLOWED TO REPRODUCE	PROGENY		
		♂♂	♀♀	Total
Original ♀♀	23	201	253	454
F_1 ♀♀	124	18[1]	46	64
F_2 ♀♀	46	90[2]	7[2]	97

[1] 1 or several males not counted.
[2] Number in progeny unknown in one instance and not included.

foliage of separate cultures was allowed.

When the mated females had laid a number of eggs and the eggs had begun to hatch, the original females were removed to prevent the possibility of re-mating with any male offspring. The F_1 offspring, when matured, were counted according to sexes. Usually one to four F_1 females and several males were then placed together on another plant. This was repeated until either all the F_1 generation or as many as desired were on new plants. The same process was repeated with the F_2 generation and several succeeding generations in those instances where the fertility made these generations possible.

After the eggs laid by the F_1 females had hatched, the F_1 females were removed and mounted for later study. If the F_1 females did not lay eggs or if they laid sterile eggs, they were usually permitted to remain on the host plants for about 2 weeks before being removed and mounted. This gave ample time for possible reproductions. F_2 mothers were similarly saved for study.

CROSSES BETWEEN *Tetranychus multisetis* FEMALES AND *T. bimaculatus* MALES.—Twenty-four crosses of female *T. multisetis* with male *T. bimaculatus* were made between August 30 and October 13, 1950. Of these 24-crosses, 23 resulted in progenies. In one case the female escaped before laying eggs. A summary of the ratio of sexes produced from these matings is presented in table 1.

The results indicated a decided general decline in the fertility of the females in the generations following the original crosses. This decline in the fertility of the F_1 and F_2 females would appear to be even greater by comparison if the original

Table 2.—Number of females and males resulting from the matings of *Tetranychus multisetis* females with *Tetranychus bimaculatus* males and the inbreeding of the F_1 and F_2 generations.

CROSS	F_1 PRODUCED		F_1 USED IN INBREEDING		F_2 PRODUCED		F_2 USED IN INBREEDING		F_3 PRODUCED	
	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
1	17	5	1	0	0	0				
2[1]	0	2	—	—						
3	9	2	1	1	0	0				
4	4	1	1	1	0	0				
5	4	5	1	1	0	0				
6	8	5	1	1	0	0				
7	16	8	1	1	0	0				
8	11	10	1	1	0	0				
9	7	14	1	1	0	0				
10	23	6	1	1	0	0				
11	8	7	1	1	0	0				
12	3	8	1	1	0	0				
13	19	12	13	12	10	1	10	1	0	0
14	13	19	13	13	11	2	11	2	0	0
15	12	11	10	8	4	5	4	2	[2]	11[2]
16	1	2	1	1	0	0				
17[1]	—	—								
18	13	16	12	10	3	1	3	1	0	0
19	28	12	16	9	1	4	1	2	0	0
20	16	14	16	14	3	1	3	1	0	2
21	8	14	8	9	2	1	2	1	0	0
22	9	9	6	9	0	0				
23	9	7	7	7	6	2	6	2	7	77[3]
24	15	12	11	12	6	1	6	1	0	0

[1] Female escaped.
[2] Some females, at least 11 males, F_4, F_5 produced, then inbreeding discontinued.
[3] F_4, F_5 produced, then inbreeding discontinued.

females used in the crosses had not been removed soon after the first eggs began to hatch but allowed to lay all the eggs they could. Of the 23 original crosses all except two failed to produce females beyond the F_3 generation. The two exceptions continued to produce both males and females until the F_5 generation when further inbreeding was discontinued. Table 2 shows the number of generations, number of offspring and their sexes resulting from each cross made.

It is of interest to note that females of the F_1 generation differed considerably in their reproductive capacity. Some females failed to lay eggs, some laid eggs that were all sterile, and still others produced eggs of which some were sterile. In the case of the F_2 females most of them did not produce offspring.

All female progenies from F_1 to F_5 showed the same carmine coloration which characterized the original females used in the crosses.

Of the female progenies produced, 221 F_1, 34 F_2 and 6 F_3, or a total of 261 were mounted on slides for study.

Examination under the microscope showed that all the female progenies had setation of tarsus I and tibia I typical of the original females, namely, six setae proximad to the duplex setae on tarsus I and 13 setae on tibia I. Variation of five or seven setae on tarsus I and 12 or 14 setae on tibia I were noted in several instances. No instance was found of females in any generation having the setation of *Tetranychus bimaculatus*, *i.e.* four setae on tarsus I proximad to the duplex setae and 10 setae on tibia I.

CROSSES BETWEEN *Tetranychus bimaculatus* FEMALES AND *T. multisetis* MALES.—Between November 6, 1950 and January 18, 1951, 40 matings were made using *T. bimaculatus* females and *T. multisetis* males. In four instances the females escaped, leaving 36 crosses from which data were obtained. A summary of the ratio of sexes produced from these matings is presented in Table 3.

Again a general decline in the fertility of the females in the generation following the original crosses was observed. In these crosses no attempt was made to continue the inbreeding beyond the F_3 generation. Here also most of the reproductive capacity of the F_1 and F_2 females was expressed by several of the females as was the case in the previous series of crosses.

Table 3.—A summary of sexes produced by matings of *Tetranychus bimaculatus* females and *T. multisetis* males.

GENERATIONS	No. ♀♀ ALLOWED TO REPRODUCE	PROGENY		
		♂♂	♀♀	Total
Original ♀♀	36	226[1]	266	492
F_1 ♀♀	183	5[1]	53	58
F_2 ♀♀	49	17[2]	60[2]	77

[1] At least this many males.
[2] Several nymphs of undetermined sexes not included.

All F_1 females were carmine in color and not green as were the original females of this series of crosses. No difference could be detected between the carmine color of these F_1 females and the carmine color of normal *Tetranychus multisetis* females.

However, the F_2 and F_3 females produced were either a carmine or green or changed color from green to carmine. It was observed in *Tetranychus multisetis* that recently matured females normally appear green but became a characteristic carmine in a day or so. In the case of the F_2 and F_3 generations female progenies of *T. bimaculatus* females crossed with *T. multisetis* males, there may be a delay of 5 or 6 days before a newly matured green female would turn carmine in those instances where a change of color did occur. Even the green females were often atypical in that two smaller black areas appeared posterior to the normal two black spots on the dorsum.

Of the females produced, 236 F_1, 26 F_2 and 50 F_3, or a total of 312 were mounted on slides for study.

These 312 females were examined under a microscope, and the setation of tarsus I and tibia I was found to be typical of the original *Tetranychus bimaculatus* females, *i.e.* four setae proximad to the duplex setae on tarsus I and 10 setae on tibia I. There were a few instances in which the number of setae varied from those given, but no instance in which the setation was like those of *T. multisetis*.

Details of the results of the crosses between *Tetranychus bimaculatus* females and *T. multisetis* males are given in table 4

DISCUSSION.—The crossing of female *Tetranychus multisetis* and male *T. bimaculatus* and the reverse crossing resulted in progenies of both sexes indicating that fertilization of the females occurred quite

Table 4.—Number of females and males resulting from the matings of *Tetranychus bimaculatus* females with *Tetranychus multisetis* males and the inbreeding of the F_1 and F_2 generations.

	F_1 Produced		F_1 Used in Inbreeding		F_2 Produced		F_2 Used in Inbreeding		F_3 Produced	
Cross	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂
1[1]	0	3								
2[1]	—	—								
3[1]	—	—								
4	4	7	2	5	0	0				
5	8	14	5	11	0	0				
6	5	6	4	5	0	0				
7	6	6	6	6	0	0				
8	11	4	9	4	0	0				
9	26	3	8	3	0	0				
10	15	3	5	3	0	0				
11	17	3	6	3	0	0				
12	16	5	12	5	24	2[2]	24	2	56	17
13	8	2	8	2	0	0				
14	18	1	11	1	0	0				
15	10	0	6	0	0	0				
16	11	4	7	4	1	1	1	1	1[1]	0
17	15	4	7	4	0	0				
18	19	4	4	1	6	0	6	0	0	0
19[3]	—	—								
20	2	8	2	2	[4]	[4]				
21	1	3	1	3	0	0				
22[1]	0	3								
23[1]	0	2								
24	5	[5]	2	0	1	1	—	—		
25	7	6	7	6	4	0	4	0	0	0
26[1]	0	4								
27	3	2	3	2	0	0				
28	10	17	10	7	2	0				
29[6]	0	29								
30[2]	9	10	9	6	11	1[2]	10	1	3	0
31	8	7	8	7	0	0				
32[1]	0	3								
33[1]	—	—								
34[6]	0	9								
35[6]	0	22								
36	3	9	3	2	0	0				
37[1]	0	3								
38	1	10	1	1	0	0				
39[1]	0	2								
40[7]	28	8	28	8	4	0	4	0	[7]	

[1] Female escaped.
[2] At least two males.
[3] Plant died.
[4] Several nymphs, sex not determined.
[5] Male undoubtedly produced.
[6] Fertilization doubtful.
[7] Several nymphs gone; sex unknown.

readily. Subsequent inbreeding in both cases, however, showed that a substantial proportion of the F_1 generation was sterile or had reduced fertility of varying degree. Several exceptions in which the females continued fertile beyond the F_2 generation were found in the series of crosses between female *T. multisetis* and male *T. bimaculatus*. In these cases the eggs appeared to be nearly 100 per cent viable.

The setation of tarsi I and tibiae I of the females was transmitted to female progenies without being affected by the males used in mating. A similar heredity was also found to be the case in a series of crosses made by Davis[1] using *Tetranychus multisetis* and a population of carmine mites morphologically similar to the green *T. bimaculatus*. Davis, however, found the progeny of his crosses to be fertile in the F_1 generation and in succeeding generations.

The coloration of the F_1 female mites was always carmine as a result of crosses using *Tetranychus multisetis* females and green *T. bimaculatus* males as well as reverse crosses. This indicates a genetic dominance of the carmine color over the green and

[1] Ph.D. Thesis, Univ. of California, 1950.

the transmission of this character by either males or females. If color were caused by a simple dominant factor, the F_2 females should show segregation of both colors. This did occur in the F_2 generation from original green mothers, but no segregation of colors occurred in the F_2 generation from original carmine mothers. Out of 53 F_2 females from original green mothers the majority appeared green, a few were definitely carmine and several were of doubtful color (between green and carmine). As previously mentioned, some of the green F_2 females turned carmine after a lapse of five or six days.

The stock colonies maintained in the laboratory over several months on the same host plant as that used in the crossing experiment showed no change in color in any generation in the case of either *Tetranychus bimaculatus* or *T. multisetis*.

Tetranychus multisetis is southern in distribution and *T. bimaculatus* occurs primarily in the more northern temperate zone. This difference together with the results of the mating experiments indicates that the two populations represent subspecies.

SUMMARY.—1. Green-colored *Tetranychus bimaculatus* were used in a series of crosses with *T. multisetis* in order to determine whether they would interbreed under laboratory conditions. An F_1 generation was readily produced from these crosses, and in some cases succeeding generations were obtained.

2. *Tetranychus multisetis* McGregor differs from *T. bimaculatus* Harvey by having six setae proximad to the duplex setae on tarsus I and 13 setae on tibia I of the female rather than four setae proximad to the duplex setae on tarsus I and 10 setae on tibia I. *T. bimaculatus* has been reported by various authors to vary in color. *T. multisetis* is always carmine.

3. Twenty-three crosses using *Tetranychus multisetis* females and *T. bimaculatus* males were made. The female progenies were like the original females in setation and color in all cases through the F_4 generation when this generation was attained. The overall fertility of the F_1 females was markedly less than the original females with individuals varying from complete sterility to low fertility.

4. Thirty-six crosses using *Tetranychus bimaculatus* females and *T. multisetis* males were made. The female progenies of these crosses through the F_3 generation all possessed leg setation similar to the original females. All of the F_1 females were of a carmine color typical of *T. multisetis*. However, the F_2 generation showed both green and carmine coloration with green females predominating. It was noted that some F_2 females exhibited a change in color from green to a typical carmine after five or six days.

5. No decline in fertility was noted in the stock colonies of either *Tetranychus bimaculatus* or *T. multisetis*. These colonies were maintained throughout the course of the mating experiments.

6. Experimental results together with a consideration of differences in geographical distribution indicate that *Tetranychus multisetis* is a subspecies of *T. bimaculatus*.[1]

[1] *Acknowledgments.*—The author wishes to acknowledge the guidance and helpful suggestions of Dr. A. Earl Pritchard; and express appreciation to Drs. A. E. Michelbacher and Edward A. Steinhaus in reading the manuscript and to Mrs. H. K. Sharsmith for identifying the host plant used in this experiment.

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Control of the European Chafer in Pasture Sod

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During its larval stages, the European chafer *Amphimallon majalis* Razoumowsky, feeds extensively upon the fine roots and root hairs of fibrous rooted plants, particularly grasses, clovers, and small grains. In sod areas, the roots of grasses and clovers may be so ravaged that the plants are unable to obtain sufficient moisture to survive, and in this way pastures and hay crops are often severely damaged.

The European chafer infestation is located in Monroe, Ontario and Wayne counties of New York. In this area there are many hillsides that are too inaccessible to allow economic crop rotation practices to be carried out on them, but which are satisfactory locations for permanent pastures. Within the area infested by the European chafer, most pastures support larval populations which are sufficiently heavy to cause a serious reduction in yield of foliage during the grazing season. In all cases, the larvae do enough damage for the insect to be considered an important economic pest.

Permanent pasture sod in the form of pasture land, therefore, constitutes a major portion of the total area that more or less continuously harbors infestations of the European chafer, and if a general program of control is eventually to be inaugurated, it must necessarily be concerned with these primary sources of infestation. Gambrell (1946) found that DDT, applied to lawn turf as a suspension at the rate of 30 and 50 pounds per acre, appeared promising for the control of European chafer larvae, and that lead arsenate, applied at the rate of 500 pounds per acre would afford commercial control. Currently, it appears that an application of 50 pounds of DDT to the acre on turf will give excellent protection from the larvae for 2 to 4 years; 25 pounds of DDT or 10 pounds of chlordane per acre will afford satisfactory control in turf where a small amount of injury may be tolerated. The cost of materials for any one of these treatments, however, makes its use on low value pasture land prohibitive. Consequently, only low cost insecticide treatments for European chafer larval control can be economically applied to permanent pastures. Furthermore, particularly in the case of pastures on steep hillsides, it is often difficult to get application equipment onto the areas to be treated. Preliminary investigations of this problem, involving several insecticides at low rates of application, were begun in 1947 and greatly expanded in 1949 and 1950.

Methods and Materials.—One group of soil treatments was applied during the late fall of 1949, and another group was applied in the early spring of 1950. Both the spring and fall applications included treatments of parathion, dieldrin, aldrin, chlordane, benzene hexachloride, and DDT, each at several concentrations (Tables 1 and 2). Late fall, after the livestock have been removed from the pasture for the winter, was considered to be the most practical time for the application of insecticides to pasture soil, since this procedure allows several months to elapse before the animals are returned to the pasture. The probability of any livestock being affected by insecticide residues on the foliage is thus very much reduced. The spring application was included in the experiment to determine whether or not the treatment applied at this time could still substantially reduce the larval populations present in the soil at the time of application.

The materials were all applied, in dust form, from a hand operated fertilizer spreader, to plots 10 by 20 feet. The treatments for the fall and spring applications were randomized together, and the plots were laid out on a steep hillside permanent pasture near Port Gibson, in Ontario county, New York. Each application of each treatment was replicated 3 times. European chafer larvae counts in the plots were made by removing samples of soil, each 12 inches square and 6 inches deep, and examining them for larvae. A fixed number of samples was selected from each plot at each date of sampling. Two months after the fall application, three soil samples were examined from each plot, and the average number of larvae obtained from each treatment was determined

[1] The authors wish to express their appreciation to the following men who assisted in the work reported in this paper: Lemac Hopkins, Donald S. Marshall, and Arthur A. Muka.

Table 1.—Effect of soil treatments in the fall with parathion, dieldrin, aldrin, chlordane, benzene hexachloride, and DDT, applied as dusts from a hand-operated fertilizer spreader, to control European chafer larvae. Stacy Farm, Port Gibson, N. Y. September 25, 1949.

Material	Actual Toxicant in Lbs. per Acre	Av. No. of Larvae per 3 Sq. Ft.
	2 Month Count	
Parathion	1	4.66
Parathion	2	4.33
Parathion	5	0.66[1]
Dieldrin	1	2.66[1]
Dieldrin	2	2.00[1]
Aldrin	1	3.33
Aldrin	2	4.60
Aldrin	5	4.33
Chlordane	1	10.33
Chlordane	2	9.00
Chlordane	5	11.33
BHC	0.5	7.66
BHC	1.0	4.00[1]
BHC	2.0	2.00[1]
DDT	2.5	12.00
DDT	5.0	8.66
DDT	10.0	7.33
Check	—	11.66
L.S.D. at the 1% level		7.3
	8 Month Count	
Parathion	1	8.30[2]
Parathion	2	4.00[2]
Parathion	5	1.66[2]
Dieldrin	1	6.00[2]
Dieldrin	2	0.66[2]
Aldrin	1	1.66[2]
Aldrin	2	4.00[2]
Aldrin	5	0.33[2]
Chlordane	1	19.00
Chlordane	2	22.00
Chlordane	5	11.66
BHC	0.5	5.33[2]
BHC	1.0	4.66[2]
BHC	2.0	1.00[2]
DDT	2.5	11.33
DDT	5.0	5.00[2]
DDT	10.0	3.00[2]
Check	—	19.66
L.S.D. at the 1% level		11.10

[1] Highly significant reduction in population.
[2] Highly significant reduction in population.

(Table 1). The data obtained show that, by 2 months after the time of the fall application, parathion applied at the rate of 5 pounds per acre, dieldrin at 1 pound per acre, and benzene hexachloride at 1 pound per acre of gamma isomer, had each produced a highly significant reduction of the larval population. Eight months after the date of application, three soil samples were again selected from each plot, and examined for larvae. The results obtained (Table 1) show that by this time, parathion at 1 pound per acre, benzene hexachloride at 0.5 pound of gamma isomer per acre, aldrin at 1 pound per acre, and DDT at 5 pounds per acre, had also caused a highly significant reduction in the larval population.

Five weeks after the spring application, the effectiveness of each of these treatments was determined (Table 2). Significant controls with each of parathion at 5 pounds per acre, and dieldrin at 5 pounds per acre, were obtained at that time. None of the aldrin, chlordane, benzene hexachloride or DDT treatments had yet significantly affected the European chafer larval population.

The 1950–51 larval populations were too low, in the area of the treatments, for any useful data to be obtained, but in the fall of 1951 the fall application plots were examined for larvae of the 1951–52 population. At this time, five soil samples were examined from each plot, for the infestation was still light in comparison with that observed in 1949. Table 3 shows that a highly significant degree of control of

Table 2.—Effect of soil treatments in the spring with parathion, dieldrin, aldrin, chlordane, benzene hexachloride, and DDT, applied as dusts from a hand operated fertilizer spreader, to control European chafer larvae. Stacy Farm, Port Gibson, N. Y. April 17, 1950.

	5 Week Count	
Material	Actual Toxicant in Lbs. per Acre	Av. No. of Larvae per 3 Sq. Ft.
Parathion	1	9.0
Parathion	2	6.0
Parathion	5	3.6[1]
Dieldrin	1	8.3
Dieldrin	2	8.3
Dieldrin	5	4.0[1]
Aldrin	1	11.6
Aldrin	2	10.0
Aldrin	5	9.0
Chlordane	1	15.0
Chlordane	2	17.6
Chlordane	5	14.6
BHC	0.5	14.6
BHC	1	4.6
BHC	2	8.6
DDT	5	13.6
DDT	10	14.0
DDT	15	7.6
Check	—	15.3
L.S.D. at the 5% level		10.4

[1] Significant reduction in population.

the larvae was obtained with each of the following treatments: dieldrin at 1 pound per acre, aldrin at 1 pound per acre, benzene hexachloride at 2 pounds of gamma isomer per acre, and DDT at 5 pounds per acre (Table 3). Each of these four treatments, then, had effectively controlled three generations of European chafer larvae from the fall of 1949 to the fall of 1951. It is assumed that, since these treatments controlled the 1951–52 larvae, they would have been at least equally effective against as heavy a 1950–51 population.

DISCUSSION.—The 1949 fall treatments, and the 1950 spring treatments were applied on the same third instar of the European chafer of the 1949–50 generation. The third stadia begin to appear in the late summer or early fall, and the larvae remain in this form until middle to late spring of the following year when they pupate. Tables 1 and 2, then, indicate the effectiveness of the treatments against the third stadia of the 1949–50 population, when the insecticides were applied in the late fall and early spring. By the late spring of 1950, low rates of application of all of the insecticides, except chlordane, appeared promising as larval controls for one generation of the European chafer. Parathion and dieldrin gave the most rapid control, however, being effective within 5 weeks after the spring application (Table 2). The residual actions of the insecticides against ensuing larval populations would not necessarily have to control third instar larvae, however, since the toxicants would be present in the soil to affect the more easily killed first instar larvae. Parathion, however, appeared to have no significant residual action against even first instar larvae, while dieldrin, aldrin, benzene hexachloride, and DDT each effectively controlled the 1951-52 population (Table 3). Since there is some danger that benzene hexachloride soil residues might eventually cause undesirable flavors in future food crops in any treated area, the use of dieldrin, aldrin, or DDT at low rates of application appeared to be most promising for the control of European chafer larval populations in pasture sod.

Table 3.—Effects of fall soil treatments of September 25, 1949 with parathion, dieldrin, aldrin, chlordane, benzene hexachloride, and DDT, applied as dusts from a fertilizer spreader, to control European chafer larvae. Stacy Farm, Port Gibson, N. Y. October, 1951.

MATERIAL	ACTUAL TOXICANT IN LBS. PER ACRE	COUNTS TAKEN 24 MONTHS AFTER APPLICATION THIRD GEBERATION OF LARVAE: AV. NO. OF LARVAE PER 5 SQ. FT.
Parathion	1	9.3
Parathion	2	5.33
Parathion	5	3.0
Dieldrin	1	0.0[1]
Dieldrin	2	0.0[1]
Aldrin	1	0.0[1]
Aldrin	2	0.3[1]
Aldrin	5	0.0[1]
Chlordane	1	9.6
Chlordane	2	5.0
Chlordane	5	5.0
Benzene hexachloride	0.5	16.66
Benzene hexachloride	1	3.0
Benzene hexachloride	2	1.6[1]
DDT	2.5	3.0
DDT	5	0.6[1]
DDT	10	0.0[1]
Check	—	11.0
L.S.D. at the 1% level		8.96

[1] Highly significant reduction in population.

SUMMARY.—Dieldrin, applied at the rate of 1 pound per acre, aldrin at 1 pound per acre, and DDT at 5 pounds per acre, gave good control of 3 consecutive European chafer larval populations in pasture sod, from 1949 to 1951, when the treatments were applied during the fall of 1949 on the third instar grubs. All materials were applied in dust form. Dieldrin appeared to have the most rapid toxic action of these three insecticides. Benzene hexachloride, when applied at the rate of 2 pounds of gamma isomer per acre also gave effective control of the same three generations but, as it is possible that it might affect the taste of future food crops in the treated area, its use is less desirable than that of DDT, aldrin, or dieldrin. Chlordane, when applied at the rate of 5 pounds per acre, was not effective in reducing European chafer larval populations in the treated plots.

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Control of Sweet Clover Weevil in Ohio

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Control methods directed against the sweet clover weevil, *Sitona cylindricollis* Fahr., may be divided into two major categories: Measures which have been used in combatting the pest in established stands, and those directed toward the protection of new seedings.

The weevil was observed as a serious pest in Ohio as early as 1943, due to the destruction of new seedings of sweet clover by the adults. They attack the plants before and after they appear above the surface of the soil, either completely destroying or severely defoliating the seedlings, and have made it increasingly difficult to obtain satisfactory stands.

The present study covering 1950 and 1951 was conducted in cooperation with the Department of Agronomy of the Ohio State University and the U.S.D.A. Legume Seed Research Laboratory in Columbus, Ohio. The major emphasis was directed to a consideration of the factors leading to the protection of new seedings until the plants have reached a stage of development necessary to successfully withstand the attack of the weevil.

The migration ability of the weevil remains an unsettled question. It is extremely difficult to find volunteer plants, even at great distances from established fields, that have escaped attack. Bird (1947) reports the same condition in Manitoba. Munro *et al.* (1949) report that in North Dakota new seedings receive a fair degree of protection if located at least a half mile from established stands. The widespread use of strip cropping in Ohio has tended to place seedings more closely, and distances as great as a half mile would be rare.

Increased rates of seeding have been suggested by Hackleman & Farrar (1943). They state that in Illinois from 10 to 15 pounds of seed per acre on a well prepared seed bed should give a good stand, even in spite of weevil damage. The seeding rate in the present study was 12 pounds per acre. No experimental area was available to determine the effectiveness of varied rates of seeding.

Delayed seeding of new stands has been recommended by Munro (1944). He states that in North Dakota delayed seeding gave 90 per cent of a normal stand, compared with 5 per cent of a normal stand in plots seeded at the usual time. Hackleman & Farrar (1943) state that in Illinois good stands may be obtained by seeding during the first half of July. A majority of the sweet clover in Ohio is seeded in the early spring months, utilizing small grains as nurse crops.

Observation has indicated that active migration by flight of the overwintering generation is in progress by late April and has passed the climax by late May. In 1950 two plots of ground each 250 by 30 feet were prepared for new seedings. They were seeded without a companion crop on April 22, and May 20. Data were taken from each plot on June 17, or must prior to the dispersal of the newly emerged generation of adults.

Five samples of 100 trifoliate leaves were taken from each plot and the feeding notches counted. The plants from the early seeding showed 86.6 per cent feeding injury, and those from the later seeding showed 20 per cent feeding injury. The success of late seedings of legumes is also contingent upon adequate rainfall and favorable climatic conditions in general, and are therefore generally avoided. The seedlings from the late seeding were not vigorous or well developed, at least partially due to lack of rainfall.

Fields of clover were observed near Columbus in both 1950 and 1951 which were plowed for green manure after the middle of May and the ground immediately prepared for corn. Soil sifting gave no recovery of larvae after one week. Laboratory oviposition records showed that by this date 85 per cent of the total oviposition had occurred. Delayed plowing of the acreage of sweet clover to be used for green manure therefore appears effective in trapping most of the new generation while in the immature stages. Early spring seedings of clover are ordinarily sufficiently developed by this time to overcome the defoliation resulting from the increased population of adult weevils migrating from the plowed fields.

Delayed plowing had little or no effect in reducing the old generation. Adults were observed congregated at the field

margins and migrating from the plowed fields.

Varietal resistance was observed on the variety plots at the Ohio State University Farm. Varieties producing the earliest spring foliage and in the greatest quantity appeared less damaged than late maturing varieties or those with little foliage. The data taken were based on the number of feeding notches per 100 trifoliate leaves. Munro *et al.* (1949) pointed out that the value of varietal resistance remains uncertain, since it is not established that resistance would be present if the weevil had little choice in selecting the host variety, instead of a wide range of host varieties. No variety of sweet clover has been reported to be immune to attack from the weevil.

Munro (1949) and Munro *et al.* (1949) state that no insecticidal treatment of new seedings has been effective in North Dakota.

Wilson (1951), in Indiana, recommends the application of 2 pounds of DDT (actual) per acre with a low pressure sprayer, or the application of 2 pounds of the same material formulated with fertilizer and used as a top dressing. The fertilizer used in preliminary tests was superphosphate, but it is believed that the insecticide might be more effective if applied with a fertilizer containing both phosphorus and potassium. Wilson also states that seedings may be protected by airplane applications, although not as effectively as by ground dusting. The recommended rate of application is 30 to 35 pounds of a 5 per cent dust.

The possibility of applying insecticides to new seedings of sweet clover was investigated in Ohio in both 1950 and 1951. The 1950 seeding was made on April 20, of a yellow variety, and with no companion crop. The individual plots were 20 by 20 feet, replicated 4 times, and arranged in a randomized block. The 1951 seedings were made on April 25, of one yellow and one white variety, with oats as a companion crop, and received 250 pounds of 0–20–20 fertilizer per acre. Individual plots were 16 by 26 feet, replicated four times and arranged as in 1950.

Insecticides were formulated as 1 per cent dusts and applied as a top dressing to the soil with a small fertilizer spreader. In 1950 benzene hexachloride was applied at the rate of 1.25 pounds of gamma isomer per acre, and all other insecticides at 5 pounds per acre. In 1951 the insecticides were applied at the rate of 5, 3, and 1 pounds of toxicant per acre.

Two dates of application were chosen in 1950, corresponding to the stage of plant development. The first application was made after most of the plants were through the soil and the other was made one week later. The 1951 treatments were applied just as the seedlings were beginning to break the surface.

Data were taken at the end of the first and second weeks after treatment in 1950. In 1951 the data were taken three weeks after application.

The insecticides were rated on the basis of plant injury. The number of plants and the number showing definite feeding notches of the weevil were counted and recorded from 5 square feet in each plot. The numbers were changed to percentages of damaged plants, the percentages reduced to angles using an arcsine transformation, and subjected to statistical analysis. The data from the 1950 applications are summarized in Table 1. They were subjected to an analysis of variance to investigate differences due to treatment, block, and time of application.

The early readings for plant injury were significantly greater than the late readings, emphasizing the necessity for early application of insecticides if the plants are to be protected from feeding injury. Telford and Munro (1943) have observed that the amount of injury to stands is correlated with the amount of foliage present. This correlation is also illustrated in the data taken at 2 weeks after treatment from the late applications. The drop in plant injury in the plots was partially due to the seedlings having attained a stage of development for rapid foliage production. The check plots showed a very sharp drop in plant injury.

The insecticides were not in an orderly arrangement at the end of the first week in early or late applications. This is apparently due to a more uniform distribution of injury at the time of application, and lack of sufficient time for the effects of insecticide treatments to become evident.

The results agree in rating the insecticides in the same position at the time of the second reading, or 2 weeks after treatment, with one exception. Benzene hexachloride and chlordane changed posi-

Table 1.—Insecticide rating based on seedling injury (1950).

Treatment and Rate per Acre	Per Cent Plant Injury		Treatments Significantly Less Injured[1]	
	1 Week	2 Weeks	1 Week	2 Weeks
			(Early Application)	
0. Check	10.81	17.55	All	All
5. DDT	3.58	2.27	BHC, Methoxychlor	Chlordane, Heptachlor
5. Chlordane	3.51	1.07	None	None
5. Heptachlor	3.29	0.43	None	None
5. BHC[2]	2.77	1.46	None	Chlordane, Heptachlor
5. Methoxychlor	2.70	9.62	None	DDT Chlordane, Hep. BHC
			(Late Application)	
0. Check	12.94	5.54	All	All
5. DDT	5.03	0.24	Chlordane, BHC, Methoxychlor	None
5. Chlordane	2.88	0.22	None	None
5. Hepatchlor	4.96	0.00	Chlordane, BHC, Methoxychlor	None
5. BHC[2]	2.74	0.18	None	None
5. Methoxychlor	3.86	1.11	Chlordane, BHC	None

[1] Significant at 5% level.
[2] Containing 25% Gamma Isomer.
Analysis by the Ohio State University Statistics Laboratory.

tion in the rating scale on the late application, but show no significant difference in their effectiveness. Heptachlor was the most effective of the insecticides tested and methoxychlor the least effective.

The results of the 1950 tests were used as the basis for continued studies in 1951. Methoxychlor was deleted from the test insecticides since it exerted the least control in 1950. Benzene hexachloride was omitted because of the possibility of undesirable residues remaining in the soil.

The application of insecticides was started on May 3, or 8 days after seeding, and was completed on May 5. The plots were observed until May 24, at which time the clover plants were of sufficient size to be readily counted. The data are summarized in Table 2.

The stand in the plots of the white variety was extremely poor, due at least in part to dry weather, resulting in conditions unsatisfactory for securing accurate data; a fact which was reflected in the data obtained. It was observed that the weevils were attracted to the yellow variety more than the white, evidently due to the much better stand. The data from the white variety are presented but not considered to be of major importance in evaluating the insecticides.

The 5 pound applications were all subjected to an extremely heavy wind and rain storm immediately after application. This condition prevented an accurate comparison of the data from each of the three levels. The remaining levels of application were not subjected to rain for

Table 2.—Insecticide rating based on seedling injury (1951).

Treatment	Per Cent of Application Plant Injury			Mean	Significantly Less Injured[1]
	5 lb.	3 lb.	1 lb.		
				(white)	
Check	20.4	19.0	13.1	17.50	Heptachlor Aldrin
DDT	10.6	10.1	29.3	16.70	Heptachlor Aldrin
Heptachlor	6.0	5.5	17.4	9.36	None
Chlordane	8.25	15.2	16.6	13.35	Aldrin
Aldrin	10.6	3.7	5.0	6.40	None
				(yellow)	
Check	41.8	26.4	26.9	31.70	Heptachlor Chlordane Aldrin
DDT	22.2	15.8	29.6	22.54	Heptachlor Aldrin
Heptachlor	0.9	6.7	25.6	11.06	None
Chlordane	7.6	13.7	22.8	14.70	Aldrin
Aldrin	4.8	3.5	8.5	5.59	None

[1] Significant at 5% level.

over a week after application, and were therefore applied and observed under more comparable conditions.

The data indicate that the severe rainfall did not destroy the effectiveness of the 5 pound treatments. DDT gave least control, or a reduction of 46.9 per cent in plant injury. Heptachlor gave near perfect protection, while chlordane and aldrin gave respectively 81.8 per cent and 88.5 per cent reduction in injury.

The data from treatments at the rate of 3 pounds indicate that aldrin remained very effective, giving 86.7 per cent reduction in plant injury. The effectiveness of aldrin and DDT were least reduced, while the effectiveness of heptachlor and chlordane were materially reduced at this dosage.

Treatment with 1 pound of toxicant per acre was ineffective, with the exception of aldrin. Moribund weevils were recovered from the plots treated with aldrin for three weeks after application of the insecticide. The application of 1 pound of aldrin per acre gave a reduction in feeding injury on white clover of 61.8 per cent and on yellow clover of 68.4 per cent.

The plots treated in 1950 were examined in May 1951 to determine if soil residues had prevented the establishment of a larval population in the second year growth. It was found that no treatment had prevented the establishment of larvae, and that no constant or evident difference in the population density could be determined at that time. The plots were to be plowed and the population could not be accurately determined, since many larvae were extremely small and difficult to recover.

SUMMARY.—Delayed plowing of the acreage of sweet clover to be used for green manure until after May 15 will effectively destroy as high as 85 per cent of the new generation while in the egg or larval stages.

The destruction of new seedings of sweet clover by the sweet clover weevil may be prevented by the application of insecticides formulated as dusts. DDT, heptachlor, and chlordane were applied for two seasons. Aldrin, BHC, and methoxychlor were applied for one season. The effectiveness of the insecticides and levels of application was based on plant injury. Heptachlor and aldrin were the most effective insecticides applied. Aldrin was effective at 1 pound per acre, while the present data indicate that 3 pounds of heptachlor, chlordane or DDT are necessary, and that the insecticides decrease in effectiveness in that order. BHC for one season was approximately as effective as chlordane when applied at 5 pounds per acre. Methoxychlor rated lowest in preventing seedling injury.

Varietal resistance was observed, but no varieties were found immune to attack. Varieties developing early foliage and in the greatest quantity appeared more resistant.

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Relation between Egg Mass Abundance and Fall Populations of First-Generation Corn Borer and Justification for Insecticidal Control in Field Corn[1]

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Currently, in the north central states, insecticidal treatment is recommended for the first-generation corn borer, if as many as 50 egg masses per 100 plants are found on any one day.[3] Furthermore, the loss in yield due to borer infestation is generally estimated from records on the abundance of borers in the fall on the basis of a reduction in yield of 3 per cent per borer per plant. If there should be a quantitative relationship found between the first-generation egg population in early summer and the larval population in the fall, the loss in yield from an infestation having a particular egg mass count could be estimated readily at the time of egg deposition. Inasmuch as there have been no studies of this relationship published the present investigation was undertaken.

During the course of studies on the population of the corn borer in south central Minnesota from 1948 to 1951, data were secured on the levels of borer population at different stages of borer development. A total of 12 plantings of field corn of several common varieties were under observation. They were infested to various degrees as a result of differences in the general level of abundance of corn borers in the area during the 4 years and differences in planting dates.

Of the records taken for the intensive population study mentioned, three are of special interest in the present discussion: 1) The total number of first-generation egg masses per 100 plants for the entire period of oviposition. This number is the cumulative total of the new egg masses found during each of the semi-weekly inspections of a group of marked plants, and is considered to indicate the general level of borer infestation. 2) The highest number of egg masses per 100 plants which are found alive on any one day. This number is taken to represent the abundance of egg masses at the peak of egg deposition. 3) The number of first-generation individuals (larvae plus pupal cases) in the fall. This count is different from the fall borer population in general survey work; the latter includes the borer

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[2] Grateful acknowledgment is due to Dr. L. K. Cutkomp who permitted the use of 1951 records for this discussion, to Dr. F. G. Holdaway who offered suggestions during the preparation of the manuscript and to Mr. R. E. Hodgson, Superintendent of the S.E. Expt. Sta. of the University of Minnesota who provided field plots and material assistance.
[3] North Central Regional Publication No 22.

Table 1.—Egg mass abundance and fall populations of the first-generation corn borer in several plantings of field corn at Waseca, Minnesota.

Planting No.	Year	Minhybrid No.	Planting Date	Plants Examined	Egg Masses per 100 Plants	Highest Counts per 100 Plants, on any One Day	First Generation Larvae Plus Pupal Cases per 100 Plants in the Fall
1	1948	505[2]	May 20	400	26	12	57
2	1949	503[3]	May 23	90	174	87	150
3		503	May 17	90	57	27	76
4	1950	504[4]	May 12	40	380	177	434
5		504	May 22	40	212	90	228
6		504	May 31	40	32	12	38
7		504	June 12	40	15	15	60
8		608	May 22	40	207	83	308
9		608	May 31	40	65	32	170
10		608	June 12	40	12	10	3
11	1951	503[5]	May 20	48	121	47	135
12[1]		503	May 23	48	64	25	40

[1] Corn planted at Madelia, Minnesota. [2] 1948. [3] 1949. [4] 1950. [5] 1951.

population of both the first and the second generations. Fully developed larvae of the first-generation were distinguished from similar larvae of the second-generation by differences in their tunnels. The first-generation tunnels are much larger in diameter and have a suberized surface, whereas the second-generation tunnels closely approximate the diameter of the larvae and are lined with fresh tissue.

Values for each of these records compiled for each of the 12 plantings are presented in table 1, together with some other descriptive information on the plantings. These data are also presented graphically in figures 1 and 2. in figure 1, the plantings are arranged on the abscissa according to the general level of borer infestation (the total number of first brood egg masses per 100 plants for the entire period of oviposition). The curve shows the quantitative relationship between the total number of egg masses and the highest number of egg masses present on any one day. The linear nature of this curve indicates that the peak of egg deposition is directly proportional to the total number of egg masses deposited. On the basis of these data, the use of the highest number of egg masses present on any one day during the period of egg deposition as an index of the general level of infestation appears to be biologically sound.

In figure 2, the curve shows the quantitative relationship between the highest number of egg masses present on any one day and the number of first-generation individuals (larvae plus pupal cases) found in the fall. It can be seen that infestations with the same egg mass count show a considerable variation in the size of the resultant fall populations, and *vice versa*. For example, an infestation having an egg mass count of about 90 resulted in fall populations with about 150 to 300 borers per 100 plants. Yet there is a trend toward a direct proportion between the egg mass counts and the size of fall populations.

The data presented in these graphs suggest that the fall population of first generation individuals may be estimated from either the seasonal total number of egg masses or the number of egg masses at the peak of oviposition. It is clear that this method is not a perfect one, because there may be deviations from the estimates made in this manner if, for example, the weather during the season is exceptionally favorable or exceptionally adverse for the survival of eggs and larvae. In spite of the great variation, it still appears to be the best guide available in view of the fact that insecticidal treatment must be made without knowledge of the weather conditions which may prevail at some later time. It is necessary to establish more points to validate or to modify the trend of the curve suggested in figure 2.

Regarding the relationship shown in figure 1, an incidental, but nevertheless significant, point deserves mention. In 1948 there was no prominent peak in the pattern of egg deposition and at no time

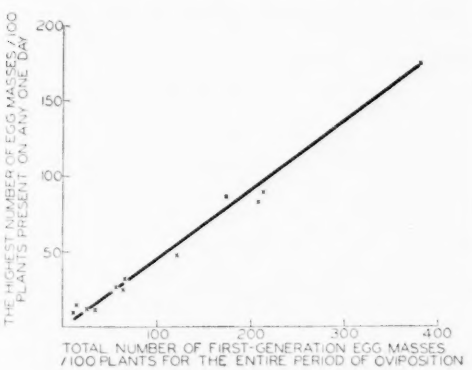

FIG. 1.—The quantitative relationship between the highest number of egg masses per 100 plants present on any one day and the total number of first-generation egg masses per 100 plants for the entire period of oviposition.

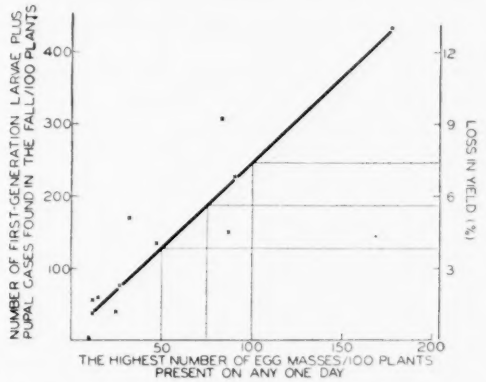

FIG. 2.—The quantitative relationship between the highest number of egg masses per 100 plants present on any one day, the number of first-generation individuals (larvae plus pupal cases) found in the fall, and the per cent loss in yield.

were 50 egg masses per 100 plants found. Yet to some entomologists and growers the infestation appeared heavy later in the season. Consequently, there was some question as to whether the 50 egg mass count truly indicated the critical level of infestation at which treatments should be made. However, our 1948 records, as illustrated by planting 1, in table 1, show that the borer infestation of that year actually was low in comparison with the infestations of the following years, probably too low to have justified treatment. Thus it appears that the highest number of egg masses per 100 plants on any one day gave a good indication of the general level of infestation, irrespective of the presence or absence of a definite and prominent peak in the pattern of egg deposition.

Results shown in figure 2 have special significance with respect to the economic aspect of the recommendations for control. As we have mentioned, the loss in yield is estimated from the level of the fall borer population based on a factor of 3 per cent loss in yield per borer per plant. In the present discussion, we also shall use this factor in estimating the loss in yield due to infestation by first brood borers in the 12 plantings. However, there are two points which need to be clarified. First, it must be recognized that the factor of 3 per cent loss in yield per borer per plant was determined originally from a study of a single infestation (Patch *et al.* 1942). The current practice of adopting this factor to estimate the loss in yield due to the combined effect of the action of borers of both generations found in the fall is beyond the point demonstrated in the original study. In view of the fact that the types of damage done to the corn plants by borers of the two generations are different (Chiang & Hodson, 1950), the validity of the current use of the factor is still to be demonstrated by field studies. In contrast, there can be little doubt of the validity of employing this factor in estimating the loss in yield due to the action of the first-generation borers alone in a two-generation area as long as the calculation is based upon the fall population of only the first-generation individuals. Second, we are not certain that the factor of 3 per cent will be valid for the corn varieties used in this study, or for the ranges of levels of population and weather conditions involved. In the absence of a more accurate method and in view of the fact that it is being used under all conditions, we feel justified in employing it in estimating the loss in yield from borer infestations in all our 12 plantings.

On these bases we have constructed the scale on the right hand side in figure 2. The scale represents an estimate of the per cent loss in yield which can be expected when the highest number of egg masses present at the peak of egg deposition is known.

We can see readily from the graph that the loss to be expected from infestations of the first corn borer having peak egg mass counts of 50, 75 and 100 would average about 4, 6 and 8 per cent respectively if the curve represents the correct trend. Simple calculations will reveal the cost of and the return to be expected from insecticidal treatment of an infestation indicated by any particular egg mass count. Let us take an infestation with a peak egg mass count of 50 as an example. make a generous assumption that the normal yield of corn is 85 bushels per acre and that the price of corn is $1.25 per bushel. The monetary loss to be expected from infestation by the borer would be $4.46 per acre. The cost of treatment probably would closely approximate this figure. Thus, even if there were 100 per cent control there would be little to be gained by the application of an insecticide to control first brood borers in this case, unless such a treatment would bring about a substantial decrease in the size of the second brood population.

The present discussion is intended primarily to present a biological basis for evaluating the loss in yield that may be expected from corn borer infestations showing different egg mass counts. Although our calculation suggests that treating an infestation with a maximum egg mass count of 50 might bring little return, any alteration of the present recommendations must be made with careful consideration of such factors as the variation in the relationship between egg mass counts and loss in yield, the cost of treatment, the efficiency of control to be expected, the normal yield of the land, the value of the corn crop, and the complication of infestation by the second generation. At present the most unsatis-

factory aspect of the problem is the lack of a method of evaluating the loss in yield due to corn borer damage that is well adapted to take into account the diversified conditions likely to be found with respect to weather conditions, plant varieties, planting dates, soil fertility and the abundance of individuals of each generation.

Summary.—From field observations on the infestation of the first-generation corn borer in 12 plantings of field corn during 1948 to 1951, the following points are shown.

1) The greatest number of egg masses found on any one day during the period of egg deposition is directly proportional to the total number of egg masses for the entire period of egg deposition. Therefore, the use of the former record as an index of the latter appears to be biologically sound. This is true irrespective of the presence or absence of a definite and prominent peak in the pattern of egg deposition.

2) There is a trend toward a direct proportion between the highest number of egg masses found on any one day during the period of egg deposition and the number of first-generation individuals (larvae plus pupal cases) found in the fall.

3) If the method of estimating the loss in yield based upon the number of first-generation individuals in the fall and the factor of three per cent loss per borer per plant is valid, it will be possible to estimate in the early summer the amount of loss in yield from the highest number of egg masses found on any one day during the period of egg deposition.

4) The egg mass count of 50 as a critical level for insecticidal treatment needs to be reviewed with careful consideration of such factors as the variation in the relationship between egg mass counts and loss in yield, the cost of treatment, the efficiency of control to be expected, the normal yield of the land, the value of the corn crop, and the complication of infestation by second-generation borers.

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The Comparative Residual Toxicity of Fog Applications of Certain Organic Insecticides to House Flies

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Probably the most efficient method of insect control in buildings is fog applications of some of the newly developed organic insecticides. This method gives a dispersion of fine particles (10 to 20 microns) which reach every portion of a treated room or building and form a residue which is not detrimental to human health, but which is sufficient to give an enduring residual coating for insect control.

Tests were made during 1950 and 1951 to determine, both on individual experimental rooms and in commercial buildings, the relative effectiveness of fog applications of some of the newer organic insecticides against houseflies. The rooms were closed and under complete control during the entire series of tests and were uniform in conditions. The buildings on the other hand were being used commercially during these tests affording a factorial indication of the effectiveness of these materials under practical and varied climatic and structural conditions.

In all the experimental work described below a generator[1] was used for dispersing the material. It has a one third horse power motor and operates at a speed of

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[1] Turbocide Generator, Manufactured by Agricide Corporation.

18,000 rpm. The turbine generator breaks the liquid insecticide into 10 to 20 micron particle size droplets which float in the air for periods of from 30 minutes to 3 hours. By regulating the rate of flow through the generator the particle size can be altered. In general, the slower the rate of flow the smaller the particle size, within limits of 10 to 30 microns. Best results are obtained when the rate of dispersion is approximately a pint in 3 to 4 minutes.

During 1950 experimental tests were performed in rooms containing approximately 1450 cubic feet. Four ounces of liquid were dispersed in each, forming a residue of less than 7 milligrams per square foot of surface. The walls and ceilings were of painted plaster. Three materials, 3 per cent chlordane, 5 per cent DDT, and 2 per cent lindane were applied as fogs in three different rooms. In each room, 100 4-day old female houseflies were liberated periodically up to 100 days after treatment. All three treatments afforded 95 to 100 per cent mortality within 36 hours after liberation, 90 days after treatment.

In 1951 two series of tests were run. One of these was in the rooms of a dormitory building in the Ohio State University GI Village where the rooms contained approximately 1200 cubic feet of space. The walls are composed of unpainted fiberboard and the floors are wood. Two and one-half ounces of liquid were dispersed in each of these rooms and the residues were 6.5 milligrams or less per square foot of surface.

A second series of tests was conducted in the rooms of a newly erected portion of a school building where the volume of the rooms is 5400 cubic feet. Ten ounces of liquid were dispersed in each room and the residue per square foot of surface did not exceed 7.5 milligrams, the average being 5.6 milligrams per square foot of surface. The ceiling is made of perforated fiberboard. The walls are composed of blackboards, windows, and painted surface or glazed tile. The floors are asbestos tile.

Residues were determined in all tests by using large sheets of pliofilm or cellophane with a surface exposure of 6 square feet. These, placed on portions of the walls, ceiling, and floor, were weighed before and after treatment. Repeated samples showed that the residues in each situation were approximately the same which indicated the equal dispersal and distribution effected by this method.

Flies, laboratory-reared from CSMA strain 48, were liberated periodically in each room together with an adequate supply of skim milk. For each test 100 female houseflies 4 days old were used.

From the data presented in tables 1 and 2, it is obvious that chlordane and lindane are superior to dilan, methoxychlor, and DDT in controlling houseflies. Three per cent chlordane and 2 per cent lindane are practically as good as 7 per cent chlordane for a period of 60 days after treatment, after which time lindane loses its effectiveness faster than chlordane. A 5 per cent DDT gave only 44 per cent mortality of flies in 26 days after treatment.

Table 1.—Residual toxicity of various insecticides to houseflies following fog applications at Upper Arlington, Ohio, in 1951.

Treatments	Percent Mortality Following Exposure to Residue						
	Days After Treatment						
	19	26	33	44	56	63	77
Dilan, 1–400	21	8	—	—	—	—	—
Dilan, 1–800	4	1	—	—	—	—	—
Dilan, 1–1600	0	0	—	—	—	—	—
Lindane, 1%	38	6	—	—	—	—	—
Lindane, 2%	100	100	86	100	96	95	62
Chlordane, 3%	100	100	100	100	95	94	79
Chlordane, 7%	100	100	100	100	98	100	94
Methoxychlor, 8%	100	79	59	50	—	—	—
DDT, 3.5%	23	16	—	—	—	—	—
DDT, 5%	52	44	16	—	—	—	—
Diluent (Insecti-Sol)[1]	6	0	—	—	—	—	—
No Treatment	0	0	0	0	0	0	0

[1] Pennsylvania Refining Co., Butler, Pa.

Table 2.—Residual toxicity of various insecticides to houseflies following fog applications at Columbus, Ohio, in 1951.

Treatments	Percent Mortality Following Exposure to Residue								
	Days After Treatment								
	16	23	31	41	50	57	65	79	86
Dilan, 1–400	100	100	69	12	5	—	—	—	—
Dilan, 1–3200	96	100	41	8	8	—	—	—	—
Dilan, 1–6400	88	94	36	5	5	—	—	—	—
Lindane, 1%	100	100	42	19	60	19	—	—	—
Lindane, 2%	100	100	100	39	62	31	—	—	—
Chlordane, 3%	100	100	99	88	89	53	45	—	—
Chlordane, 7%	100	100	100	100	100	100	96	80	62
DDT, 3%	100	100	89	66	59	51	46	—	—
DDT, 5%	100	100	100	100	78	71	22	—	—
Methoxychlor, 8%	100	100	100	97	67	70	41	—	—
No Treatment	2	0	1	3	5	4	2	0	1

The high toxicity of chlordane and lindane is attributed to their volatility.

Volatility Tests—The first indication of the high volatility was obtained when a rearing cage containing several hundred flies was placed some two feet from the wall in a room which had been fogged a few days previously with chlordane. All of the flies in the cage died in a few hours with typical symptoms of chlordane toxicity.

In order to test the volatility effects of these materials, 12 female 4-day old houseflies were placed in each of several small screen cages, 6 by 3.5 inches, together with skim milk and these cages were suspended from the ceiling to the median height of the room and at distances of from 1 to 5 feet from the wall.

Chlordane proved to be the most volatile of these materials if toxicity is used as an index. Cages which were suspended 5 feet from a wall 40 days after treatment with chlordane showed a 100 per cent mortality to houseflies within a 20-hour exposure. Flies in similar cages suspended one foot from the wall, 110 days after the same treatment had a mortality of 90 per cent within a 30-hour exposure and 100 per cent within a 48-hour exposure.

Lindane proved second in toxicity to chlordane. Eight days after treatment with 2 per cent lindane a mortality of 100 per cent within 16 hours of exposure was obtained when flies were exposed in cages 1 foot from the treated wall. The same results were obtained when the walls were treated with 3 per cent chlordane. A 1 per cent lindane showed 64 per cent mortality in 24 hours; both 8 per cent methoxychlor and 7 per cent DDT showed a 48 per cent mortality in 24 hours. Dilan, 1 to 400 dilution, and 3.5 per cent DDT were no better than the check.

Treatments Under Practical Conditions.—More than 300 large buildings of commercial size, warehouses and supermarkets, have been treated by these fog machines during the past three years and observations have been made upon the practical control of all flies which enter these buildings, 3 species of which are especially abundant. Under practical conditions, flies can be effectively controlled for periods of from a minimum of 4 weeks to more than 3 months after the building is treated. The length of time of effectiveness will vary somewhat due to (1) the type and nature of the wall and ceiling, smooth or rough, painted or unpainted; (2) the uniformity and completeness of coverage; (3) the rapidity with which dust and other materials are deposited on the wall surface; and (4) the extent to which the residue is removed by water or covered by paint.

A building with 10,000 square feet of floor space and with a volume of 125,000 cubic feet can be treated in 15 to 20 minutes with four generators and will give an excellent control of flies for an average period of 6 weeks.

Greenhouse Tests of a Trialkyl Thiophosphate Insecticide[1]

J. P. Corkins[2] and H. N. Metcalf[3]

General Insecticide Tests.—Preliminary tests indicated the practicability of further testing of the trialkyl thiophosphate for the control of greenhouse insects. The primary purpose of the project was to determine, within the limits of available time and facilities, the practicability of using the insecticide under Montana greenhouse conditions. It was reported (oral communication) that the trialkyl thiophosphate was a systemic insecticide. This report was later substantiated by Bronson & Dudley (1951); Zattler (1951).

The insecticide was applied as a water emulsion spray containing 0.13 per cent of active ingredients. Application was made with a three-gallon hand pump, compressed air sprayer using 40 to 60 pounds pressure. Sprays were applied to all exposed plant surfaces to the point of run-off. The following insects and arachnids were involved: citrus mealybug. *Pseudococcus citri*, greenhouse whitefly, *Trialeurodes vaporariorum*, and two-spotted spider mite, *Tetranychus bimaculatus*. The results are shown in table 1.

Systemic Test.—A test was then conducted using the insecticide in the irrigation water of an African violet, *Saintpaulia sp.* Only one plant which was in full bloom was used in this test. The African violet was heavily infested with citrus mealybugs. The plant was growing in a pot containing approximately 83 cubic inches of soil. Water containing the insecticide was added in a manner which avoided contact of the insecticidal emulsion with the leaves or upper stems. During the first 4 days of this test a total of 4.8 grams of the insecticide was added to the soil. The degree of mealybug control was measured by comparing living to dead mealybugs in total counts.

Non-treated control plants continued to be heavily infested with mealybugs throughout the period of the test. Many apparently viable mealybug eggs were found on the May 16 inspection. No apparently viable eggs could be found on the May 30 inspection, but many recently killed nymphs were noted.

The plant was harshly affected by the treatment, though some of the effects were apparently due to the mealybug activities. All blossoms dropped shortly after the treatment and many of the leaves became chlorotic and died. By June 30 the plant again appeared to be healthy and all phytotoxic effects had disappeared.

General Phytotoxicity Tests.—It was considered advisable to test the phytotoxicity of the insecticide against some common greenhouse plants when applied in a manner similar to commercial use. Available conditions were such that unsprayed controls were not used either for comparing phytotoxic effects or for comparing insect populations.

All sprays were applied with a wheelbarrow type power sprayer using approximately 150 pounds pressure. A coarse spray was used and all plant surfaces were covered to the point of run-off. All plants in a greenhouse conservatory were sprayed with 0.30 per cent trialkyl thiophosphate water emulsion. This room was closed for one and one-half days after spraying which caused abnormally high temperatures. The plants were sprayed a second time, 37 days after the first spray application. The second spray application was made with a 0.09 per cent water emulsion of the insecticide.

Prior to spraying, heavy citrus mealybug, *Pseudococcus citri*, infestations were evident on a passion flower vine, *Passiflora alato-caerulea*, a grapefruit tree, *Citrus paradisi*, and a fiddle-leaf fig tree, *Ficus lyrata*. Sixteen days after the first spray application no mealybugs could be found on either of the two trees, but an occasional mealybug was noted on the passion flower vine. Several later inspections indicated complete control of the mealybugs except on the passion flower vine where an occasional mealybug could be found as long as thirty-eight days after the second spray application. A severe infestation of green peach aphid, *Myzus persicae*, was present on the

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[1] Furnished by the Pittsburgh Agricultural Chemical Company. The insecticide known as Systox or E-1059 containing 32.1% of active ingredients in an emulsion concentrate form.

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Table 1.—Results of spray tests using a 0.13 per cent concentration of a trialkyl thiophosphate insecticide applied as a water emulsion.

Fuchsi (*Fuchsia sp.*). Sprayed bench and unsprayed control bench heavily infested with citrus mealybugs and greenhouse whiteflies.	*5 days after spraying*—No living adult or nymphal whiteflies, many living pupae. All mealybugs not within a cottony mass either dead or appeared abnormal, mealybugs within cottony masses appeared normal. *27 days after spraying*—Occasional adult whitefly but no nymphs or pupae, could have come from untreated part of greenhouse. A few living mealybugs within cottony masses, none without. No apparent change in control bench. No apparent phytotoxic effects.
Passion Flower Vine (*Passiflora alatocaerulea*). One vine heavily infested with citrus mealybugs, no control bench available.	*5 days after spraying*—Many mealybugs within cottony masses, a few without. *22 days after spraying*—Few mealybugs within cottony masses, an occasional one without. No apparent phytotoxic effects.
Violets (*Viola odorata*). Sprayed bench and unsprayed control bench heavily infested with two-spotted spider mites.	*5 days after spraying*—Mite population greatly reduced, but many viable eggs noted. *22 days after spraying*—No adult, an occasional nymph, recently killed mites indicated insecticide still effective. *35 days after spraying*—No mites. No apparent change in control bench. Slight phytotoxic effects suspected five days after spraying, but none found on twenty-second day or thereafter.
Roses (*Rosa sp.*). Sprayed bench of six plants and unsprayed control bench heavily infested with two-spotted spider mites.	*17 days after spraying*—No living mites could be found. No apparent change in control bench. No apparent phytotoxic effects.
Coleus (*Coleus blumei*). Sprayed bench and unsprayed control bench heavily infested with citrus mealybugs.	*22 days after spraying*—A few mealybugs within cottony masses, none without. No apparent change in control bench. No apparent phytotoxic effects.
Pelargonium (*Pelargonium domesticum*). Sprayed bench and unsprayed control bench heavily infested with greenhouse whiteflies and citrus mealybugs.	*24 days after spraying*—No mealybugs or adult whitefles could be found, a few whitefly pupae. No apparent change in control bench. No apparent phytotoxic effects.

hydrangea, *Hydrangea macrophylla*, prior to spraying. No aphids could be found sixteen days after the first spray application and none were found on subsequent inspections.

OBSERVATIONS OF PHYTOTOXIC EFFECTS.—The following injury was observed as a result of the first spraying. An additional factor existed in that the room was closed for one and one-half days after spraying and a weather change occurred causing higher temperatures than normal.

Table 2.—Citrus mealybug control on an African violet plant when watered with 50 ml. of a 32.1 per cent trialkyl thiophosphate water emulsion on May 2, 3 and 5, 1951.

DATE	LIVING	DEAD	PER CENT CONTROL
May 2	50	0	0
May 5	9	31	78
May 7	6	39	87
May 16	0	200	100
May 30	0	>200	100

Silvernerve Fittonia—*Fittonia verschaffeltii* var. *argyroneura:* no burning seen but permanent leaf distortions evident. New growth from shoots started slowly, but was normal. The plant was fully recovered in six months.

Gardenia—*Gardenia veitchii:* rather severe leaf chlorosis evident and drop.

Amaryllis—*Amaryllis belladonna:* flowers badly burned, but no foliage injury.

Perpetual Begonia—*Begonia semperflorens:* flowers badly burned, with damage to tender terminal growth, and some pitting of leaves of older foliage.

Begonia—*Begonia foliosa:* tender terminal growth killed.

Scarlet begonia—*Begonia coccinea:* flowers burned.

Fuchsia—*Fuchsia hybrida:* buds and flowers badly burned, but no foliage injury evident.

Verschaffelt coleus—*Coleus blumei* var. *verschaffeltii:* foliage damaged on specimens exposed to

full sun. Specimens in partial shade uninjured.

Babystears—*Helxine soleirollii:* some foliage burn evident.

Bigleaf Hydrangea—*Hydrangea macrophylla:* some wilting effects evident at first, with nearly full recovery. Bracts and buds badly burned and did not develop.

Crownofthorns Euphoribia—*Euphorbia milii:* blossoms burned.

Delta Maidenhair Fern—*Adiantum cuneatum:* foliage badly burned.

Alternathera—*Alternathera spp.:* some foliage burn.

Spironema—*Spironema fragrans:* some foliage burn.

African violet—*Saintpaulia ionantha:* flowers badly burned, but no evidence of foliage injury.

Damage observations following the second spray application (0.09% water emulsion of the insecticide applied 37 days after the first spray application) were made. These observations were as follows:

Fuchsia—*Fuchsia hybrida:* petals had some burned spots but not as much as following the first application.

Azalea—*Rhododendron sp.:* Azalea flowers showed a minor amount of scorch. (Not injured by first spray, possibly because not in bloom.)

Bigleaf Hydrangea—*Hydrangea macrophylla:* There was possibly some petal burn, but the flowers were beginning to age; this may have affected the results.

Scarlet sage—*Salvia splendens:* Foliage seemed hardened, brittle and cupped. The plants were not in the palm house at the time of the first spray.

There was far less damage from this spray than from the first one, which would be expected, unless the plants had become sensitized to the spray by the first application. The begonias were not noticeably affected and covering the Saintpaulia with newspapers proved effective in protecting them from the spray.

The following plants were not noticeably injured by either spray applications:

Boston Fern	*Nephrolepis exaltata bostoniensis*
Screw-pine	*Pandanus veitchii*
Umbrella Plant	*Cyperus alternifolius*
Parlor Palm	*Collinia elegans*
Kentia Palm	*Howea forsteriana*
Philodendron	*Philodendron cordatum*
Ceriman	*Monstera deliciosa*
Wandering Jew	*Zebrina pendula*
St.-Bernard-Lily	*Anthericum liliago*
Bracketplant	*Chlorophytum capense*
Aloe	*Aloe arborescens*
Gasteria	*Gasteria sp.*
Rothschild Glorylily	*Gloriosa rothschildiana*
Sprenger Asparagus	*Asparagus sprengeri*
Fern Asparagus	*Asparagus plumosus*
Century-plant	*Agave americana*
Sansevieria	*Sansevieria sp.*
Sanders Dracaena	*Dracaena sanderiana*
Crinum	*Crinum "Cecil Houdyshel"*
Kafir-lily	*Clivia miniata*
Aztec-lily	*Sprekelia formosissima*
Bird-of-Paradise Flower	*Strelitzia reginae*
Canna	*Canna generalis*
Prayer Plant	*Maranta sp.*
Hyacinth Bletilla	*Bletilla striata*
Cattleya	*Cattleya labiata*
Sanders Peperomia	*Peperomia sandersii*
Ovalleaf Peperomia	*Peperomia obtusifolia*
Ribbon-bush	*Homalocladium platycladum*
Blood-leaf	*Iresine herbstii*
Blood-leaf	*Iresine lindenii*
Silvercrassula	*Crassula argentea*
Floppers	*Kalanchoe pinnata*
Sensitive-plant	*Mimosa pudica*
Fish Geranium	*Pelargonium hortorum*
Fancy Geranium	*Pelargonium domesticum*
Grapefruit	*Citrus paradisi*
Poinsettia	*Euphorbia pulcherrima*
Croton	*Codiaeum variegatum pictum*
Box	*Buxus sp.*
Grape-ivy	*Cissus rhombifolia*
Flowering-maple	*Abutilon hybridum*
Rose-of-China	*Hibiscus rosa-sinensis*
Passion-flower	*Passiflora alato-caerulea*
Tuberous-rooted Begonia	*Begonia tuberhybrida*
Castor-leaf Begonia	*Begonia ricinifolia*
Prickly-pear	*Opuntia sp.*
Orchid-cactus	*Ephiphyllum sp.*
English Ivy	*Hedera helix*
Periwinkle	*Vinca major*
Waxplant	*Hoya carnosa*
Carrion-flower	*Stapelia variegata*
Hairy carrion-flower	*Stapelia hirsuta*
Lantana	*Lantana camara*
Ornamental Pepper	*Capsicum frutescens*
Shrimp-plant	*Beleperone guttata*
Velvet-plant	*Gynura aurantiaca*
Candle-plant	*Kleinia articulata*
Fiddle-leaf Fig	*Ficus lyrata*
Bromeliad	*Aechmea calyculata*
Bromeliad	*Aechmea ortigiesii*
Bromeliad	*Aechmea distacantha*
Bromeliad	*Aechmea caudata*
Saunders Airbrom	*Billbergia saundersi*
Bromeliad	*Billbergia nobile*
Painted Fingernail Plant	*Neoregelia spectabilis*

CONCLUSIONS.—The trialkyl thiophosphate shows promise as a greenhouse spray for controlling two-spotted spider mites, citrus mealybugs, greenhouse whiteflies, and green peach aphids. Systemic action of the insecticide was demonstrated. The reported tests are preliminary and more complete investigations are necessary before the insecticide should be recommended for general use.

The data presented indicate that caution should be used in applying this insecticide to plants which have not been tested with it. The insecticide apparently has selective phytotoxic properties. Factors such as temperature, light exposure, varietal differences, amount of active in-

gredient in the spray, number of treatments, and frequency of treatments may be influential and should receive more consideration in future tests. This is indicated, in part, by the conflicting data presented on the phytotoxic effects on fuchsia and variable foliage damage on coleus. There was a tendency for the damage to be more prevalent on the blossoms than on the foliage. It was also evident that the first spray application in the greenhouse conservatory, using the stronger mixture (0.30 per cent trialkyl thiophosphate) which was followed by abnormal conditions in the greenhouse resulted in greater injury to the plants.

SUMMARY.—Tests were conducted using a trialkyl thiophosphate as a greenhouse spray for the control of citrus mealybug, greenhouse whitefly, and two-spotted mites. Further toxicity tests were conducted on a variety of greenhouse plants.

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Cable Type Back Rubbers for Horn Fly Control on Cattle

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The horn fly, *Siphona irritans* (L), a persistent, blood-sucking pest of cattle, may occur to the extent of several hundred or more flies per animal in the absence of control measures. These flies cluster on the poll, neck, back, shoulders, and belly of cattle. Fly infestations under range conditions in South Dakota are made up almost solely of horn flies. Under feed-lot conditions infestations usually include stable flies, *Stomoxys calcitrans* (L), and, close to buildings, house flies, *Musca domestica* L., as well. Horn flies are easily susceptible to control by residual insecticides applied to cattle, and such applications, commonly in the form of sprays, are standard practice in livestock management.

Under range conditions the effort involved in rounding up a herd of cattle plus the actual effort of spraying them is an operation of considerable magnitude. For the last several years a much simpler method of insecticide application has been finding increasing favor among cattlemen. This method, previously described by Rogoff (1950, 1951) involves the use of the cable type back rubber constructed on the ranch for about $5.00 if new materials are used. These units may be operated for as little as a few cents per head for an entire season. The back-rubber unit, set up near a water hole, feed rack, salt-lick, or wherever the cattle habitually loaf, is used by the animals without coercion of any kind. Once installed, the only further effort to the rancher is the occasional repair of the unit plus the periodic replenishment (at approximately 2-week intervals) of the insecticide. This method appeared to have such outstanding advantages over the standard spray treatment that investigations were undertaken to determine the effectiveness of the device and to analyze the possible disadvantages from its use.[3]

CONSTRUCTION AND OPERATION OF UNITS.—The cable type back rubbers used in these experiments were constructed essentially in the manner shown in figure 1. Two wooden fence posts, solidly set and braced, were installed about 16 feet apart. A cable (a chain, a wire rope, or preferably three strands of barbed wire wrapped with a fourth wire) was suspended between the posts in such a manner as to sag to within about 18 inches of the ground. The cable was then carefully wrapped with burlap sacks overlapped and then tied every 4 to 6

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[2] Approved for publication by the Director of the South Dakota Agricultural Experiment Station as Journal Series number 268.

[3] Some of the data offered in this paper has been presented at the A.A.E.E. meeting at Denver in 1950, the A.A.E.E. meeting at Cincinnati in 1951, and the Amer. Soc. Animal Prod. meeting at Chicago in 1951.

Table 1.—Formulations of insecticides used in back rubber units.

INSECTICIDE	PER CENT (W/W)	NATURE OF FORMULATION
DDT	5.0	commercial[1]
DDT	5.0	tech. in furnace oil[2]
Methoxychlor	5.0	90% tech. in furnace oil[2]
Methoxychlor	5.0	25% E. C. in furnace oil[2]
Methoxychlor	5.0	25% E. C. in water
Methoxychlor	5.0	90% tech. in xylene 7%, furnace oil[2] 93%
Toxaphene	5.0	tech. in furnace oil[2]
Lindane	0.5	20.2% E. C. in furnace oil[2]
CS-708[3]	5.0	80% E. C. in furnace oil[2]

[1] "Franklin DDT Barn Spray."
[2] "Stanolex Furnace Oil"; Standard Oil Company of Indiana.
[3] See JOUR. ECON. ENT. **55**(1): 165.

inches with binder twine. When ready for use, the burlap sacking was soaked with insecticidal solution poured from a pitcher. Approximately a gallon was required to wet the burlap. At approximately 2-week intervals thereafter, the insecticide was replenished with about two quarts of the formula used for the first soaking. Insecticides and formulations used are presented in table 1.

EFFECTIVENESS.—Table 2 presents a comparison between fly counts (mixed horn fly and stable fly populations) on 5 neighboring herds under feed-lot conditions in eastern South Dakota. One of these herds had access to a back rubber soaked with 5 per cent DDT 3 days before the first observation. A second herd, separated from the first by a barbed-wire fence, was sprayed with 0.5 per cent DDT two days before the first observation. The other three herds (no history of treatment) were selected at random in the

Table 2.—Comparison of fly counts on two adjacent herds, one with access to a back rubber and the other sprayed, and three neighboring herds with no history of treatment selected at random.

TREATMENT	OBSERVATION DATE	NO. OF CATTLE COUNTS	FLIES PER SIDE
Back rubber (5% DDT)	7/27/51	10	0.8
	7/28	10	0.6
Spray (0.5% DDT)	7/27	11	0.8
	7/28	9	0.4
Check	7/27	8	66.0
	7/28	10	100.0
	7/28	8	101.2

FIG. 1.—A cable type back rubber in use.

immediate vicinity of the first two herds. The effectiveness of both the back rubber and the spray compared with the presumably untreated checks is obvious.

A comparison for a 24 day period between the herd with access to the back rubber and the adjacent sprayed herd just described is presented in table 3. The data indicate that both methods provided equally effective control of horn flies and that no significant difference was apparent between their relative effectiveness against stable flies.

Comparative horn fly counts on adjacent herds of cattle having access to back rubbers charged either with 5 per cent DDT solution, 5 per cent methoxychlor solution, or 5 per cent methoxychlor emulsion are presented in table 4. These cattle, located in central South Dakota under range conditions, were observed on 18 separate occasions during a three week period in 1950. All units had been in operation at least 3.5 weeks before the first fly counts. Statistical analysis of this data indicates significant superiority of DDT over either of the two methoxychlor formulations, but does not indicate superiority of the methoxychlor solution over the emulsion. The use of the oil solution under field conditions, however, was much simpler than the emulsion as the latter had a tendency to harden the burlap and make replenishment difficult.

Table 5 presents comparative fly counts obtained in 1951 under range conditions in central South Dakota, on 9 adjacent herds of cattle having access to back rubbers charged with various insecticides and a check herd not so exposed. Fly counts, obtained over a 7-week period in

Table 3.—Comparison of effectiveness of back rubber (5 per cent DDT) vs. spray (0.5 per cent DDT) relative to horn fly and stable fly counts on two adjacent herds.

	HERD A (back rubber)			HERD B (sprayed 7/25/51)	
OBSERVATION DATE	Replenishment Date	Horn Flies per Side	Stable Flies per Side	Horn Flies per Side	Stable Flies per Side
7/24	7/9	13.2	0	66.3	0
7/27	7/24	0.5	0.3	0.4	0.5
7/28	7/24	0.3	0.3	0	0.4
8/10	7/24	0	8.8	0	7.5
8/17	8/10	0	7.9	0	8.8

August and September, were not started until all units had been in operation for at least two weeks. The check herd, separated by a barbed-wire fence from animals using one of the back rubbers charged with the CS-708, was not under the control of the Experiment Station and, according to advice received at the end of the season, had been sprayed several times presumably with DDT. Despite this reputed treatment it is apparent from the data that all herds having access to the back rubbers had significantly fewer flies than the check herd. Statistical treatment of the data indicates that DDT was significantly superior to either toxaphene or lindane, but no other significant differences were demonstrable within the array. It should be noted that lindane was used at one-tenth the concentration of the other insecticides.

The use of emulsifiable concentrates, diluted to 5 per cent with a solvent such as common furnace or fuel oil (formulations numbered 4, 5, 8, and 9 in table 1) apparently may be used successfully on back rubber units. At the end of the 1951

Table 4.—Comparative horn fly counts on adjacent herds of cattle having access to back rubbers charged with 5 per cent DDT solution, 5 per cent methoxychlor solution, or 5 per cent methoxychlor emulsion. Eighteen observation periods, August 21 to September 9, 1950.

TREATMENT	NO. OF CATTLE COUNTS	FLIES PER SIDE	STANDARD DEVIATION
DDT solution	305	5.3	4.0
Methoxychlor solution	147	12.6	10.3
Methoxychlor emulsion	223	15.0	16.0

Analysis of variance indicates treatment means significant at 5% level of probability.

Table 5.—Comparative fly counts on adjacent herds of cattle having access to back rubbers charged with various insecticides and a check herd reputedly sprayed several times during the season.

TREATMENT	CONC.	NO. OF CATTLE COUNTS	OBSERVATION PERIODS	FLIES PER SIDE	STANDARD DEVIATION
DDT	5%	300	15	3.4	5.5
Methoxychlor	5%	49	13	5.7	5.2
Nitroparaffin derivative	5%	291	15	6.1	6.4
Toxaphene	5%	300	15	8.0	6.5
Lindane	0.5%	238	15	11.8	14.3
Check		144	15	41.5	37.2

Analysis of variance indicates treatment means significant at 0.1% level of probability. Least significant mean difference from check at 5% level = 12.48 flies/side.

season it was noted, however, that units charged with such diluted emulsifiable concentrates had large brown strains on the soil under the lowermost portion of the sagging burlap-wrapped cable, indicating a leaching by rainfall. No such stains were apparent under units charged with oil solutions (formulations 2 and 7).

Chemical analysis of burlap taken in the fall from a back rubber unit charged 8 times during the summer of 1950 with a 5 per cent oil solution of DDT revealed 5.9 mg. of DDT per gram of burlap. This suggests the possibility that once the unit has been charged a few times with insecticidal solution, the occasional addition of solvent alone may be sufficient to recharge the back rubber.

SKIN IRRITATION INVESTIGATIONS.—At the outset of these investigations, it was suspected that the use of oil solutions on cable-type back rubbers might produce skin irritation which could negate the advantages of ease of operation and effectiveness of fly control. Harshfield & Rehfeld (1948) describe a chronic dermatosis of cattle due to such excessive oil applications as may occur with certain types of automatic applicators or as a result of excessive hand application of certain oils or oil solutions for external parasite control. Accordingly a series of patch tests were performed to determine the nature and extent of irritation produced under conditions of maximum application.

Six patches, about 3 by 6 inches in area, were clipped on either side of the midline in the region of the shoulders, back, and loin of 8 Hereford steers. These clipped areas and adjoining unclipped areas of similar size were swabbed with pledgets of cotton soaked with a 5 per cent

solution of DDT in furnace oil. All such marked areas were thoroughly swabbed the first week, all but one the second week, all but two the third week, and so on. Severe irritation was seen in both clipped and unclipped areas. The lesions were characterized by extensive exfoliation of the superficial layers. In some cases the skin became leathery and in the more severe lesions there was sufficient induration to cause breaks to appear in the surface of the skin. No loss of hair was noted. The percentage of irritation on treated unclipped areas over a 7-week period is shown in table 6. Data from

Table 6.—Irritation produced, on eight Hereford steers, in unclipped areas which had been swabbed various times at weekly intervals with a 5 per cent oil solution of DDT in furnace oil. Concurrent observations repeated seven times at weekly intervals.

Area Treated	No. of Swabbings	Observations Showing Irritation
Right shoulder	1	73%
Right back	2	59
Right loin	3	21
Left shoulder	4	80
Left back	5	57
Left loin	6	21

clipped areas was essentially the same as from unclipped areas. It is apparent that in this series of observations the area of the shoulders is the most susceptible one tested, followed in turn by the back and the loin. No relationship is apparent between the number of swabbings and the degree of irritation resulting therefrom.

After attaining some proficiency in evaluating the nature and extent of irritation produced under conditions of maximal application, observations were undertaken to determine whether such irritation might be produced on cattle having access under field conditions to cable type back rubbers. Animals having access to back rubbers at an Experiment Station ranch in central South Dakota were rounded up and driven through chutes where the shoulder region of each animal was observed visually and by palpation. During 1950, 192 such observations revealed two small lesions. Scrapings taken from these lesions were negative for parasitic mites and for ringworm. These two lesions, which might or might not have been caused by the use of the back rubbers, were sufficiently small that their presence was revealed only after careful scrutiny. Similar observations on 162 cattle in 1951 failed to reveal any skin irritation. It appears, therefore, that the amount of insecticidal solution adhering to cattle using back rubbers is insufficient to initiate acute or chronic skin irritation.

DDT Absorption Investigations.—A possible disadvantage of the use of cable type back rubbers soaked with oil solutions of insecticide might be that excessive quantities of insecticide would be absorbed through the skin. To test this possibility, it was decided to follow the fate of DDT since much information concerning the physiological responses of cattle to this insecticide was already known. Cattle having access to DDT soaked back rubbers for an entire summer were followed to slaughter where approximately a pound of fat was taken from the back and a similar sample from the neighborhood of the kidneys of each animal. For the sake of comparison, similar samples were taken from cattle sprayed 3 times at 3-week intervals with 0.5 per cent DDT suspension, the animals having gone to slaughter one week after the last spraying.

The analysis of meats and animal tissues for DDT is complicated by the presence of large amounts of fatty material. Analyses for DDT were first attempted in our laboratory on samples of fats from cattle which had had access to the cable type back rubbers. It was soon evident that the DDT content was so low that larger than customary samples would be required. The methods which were being used for fatty materials (Schechter *et al.* 1947) did not lend themselves to fat samples as large as 10 grams. Davidow (1950) described a procedure for the separation of DDT from fats by the use of a Celite column. Davidow's procedure was modified so as to handle 5 gram samples of beef fat on one column. Two 5-gram samples were run through individual columns and the filtrates were combined so as to represent 10 gram samples.

The filtrates were evaporated and nitrated using precautions suggested by Clifford (1947) and the DDT was determined colorimetrically after treating the polynitro derivatives of DDT with

sodium methylate which produces a blue color. Colorimetric measurements were made on a Beckman quartz spectrophotometer.

The results of the chemical analyses of fat taken from sprayed animals and from animals having access to DDT soaked back rubbers are shown in table 7. It is readily apparent that far less DDT is absorbed by cattle using cable type back rubbers than by animals sprayed three times with a DDT suspension at a standard recommended concentration. The data for sprayed animals are in close agreement with data presented by Bushland *et al.* (1950) who detected 15 p.p.m. in the fat of cattle treated 5 times with 0.5 per cent DDT and an average of 32.5 p.p.m. in the fat of 18 steers obtained in the vicinity of Kerrville, Texas, after the 1949 fly season.

DISCUSSION.—Automatic insecticide applicators in the form of home-made cable type back rubbers have been finding rapidly increasing favor among cattlemen. Rancher acceptance has been based on a number of obvious factors easily apparent under conditions of practical usage. The attainment of effective horn fly control without the significant interference with grazing occasioned by a round-up for the purpose of spraying is probably the most significant factor from the rancher's viewpoint. The saving in labor, the reduction in expense for holding pens and spraying equipment, and the reduction in expense for actual insecticide are all important factors contributing to the increasing acceptance of the method.

The experimental data reported in this paper indicate that highly successful horn fly control can be attained under range or feed-lot conditions. The lack of skin irritation observed and the low DDT residues found in the fat of animals having access to back rubbers of this design indicate that the insecticide is deposited primarily on the surface of the hair of the cattle using the units. In actual use, cattle rub their heads, backs, sides, and bellies on the burlap-wrapped cables. It is apparent that there is sufficient movement of the flies on the cattle to bring them in contact with the extensive but incomplete depositions of insecticide.

The solvents used for the purposes of this study were of a type that might reasonably be expected to produce skin irritation if sufficient quantities were deposited on the animals. The possibility of using refined oils of low unsulfonatable residue or of using waxes or otherwise viscous solvents to reduce the quantity of solvent deposited on any one animal has been considered. In view of the data at hand, such precautions appear unnecessary.

The possibilities of using the device under consideration for the control of other external parasites of livestock are obvious. The present paper deals primarily with the control of horn flies, relative to which pests effective control has been demonstrated. The limited data presented also indicate that stable fly control by means of cable type back rubbers is equivalent to that attained by spraying techniques. Further observations

Table 7.—Comparison of DDT residues in fat after spraying versus entire season's use of back rubber. Summary based on two analyses per fat sample per animal.

Treatment	Fat Source	Sprayings or Chargings	Year	No. of Cattle	DDT Residues Detected	
					Range p.p.m.	Average p.p.m.
Spray 0.5% DDT	Back	3	1951	12	7.3–30.1	14.6
	Kidney	3	1951	12	2.8–35.8	15.3
Summation				12	2.8–35.8	14.9
Back rubber 5% DDT	Back	7	1950	10	0.7–3.4	1.8
	Kidney	7	1950	10	0.6–4.0	1.6
	Back	4	1951	10	0.4–3.8	1.6
	Kidney	4	1951	10	0.2–1.6	0.7
	Back	6	1951	5	1.2–4.7	3.0
	Kidney	6	1951	5	1.4–5.2	3.6
Summation				25	0.2–5.2	1.8

are desirable regarding stable fly control. The use of repellents instead of or in addition to insecticides should also be considered. The possibility of eradicating lice or ticks by this method is small, though observations relative to these pests would probably be desirable. Little likelihood exists that this method would be successful in reducing infestations of cattle grubs or of mangé mites.

The advantages shown can be negated by carelessness in locating the back rubbers. They must be erected in such an area that cattle have ready access to them. Usually a watering hole, salt-lick, feed-rack, or some obvious place where the herd habitually loafs makes a desirable place for locating a back rubber unit.

The data presented in this paper should not be construed as applicable to the several continuous-type cattle oilers now on the market.

SUMMARY.—1. Cable type back rubbers, constructed and located as herein described, provide highly effective control of horn flies under range or feed-lot conditions. A five per cent solution of DDT appears to be most effective.

2. Back rubbers appear to provide as effective control of stable flies as do standard spraying techniques, though further observations on this point are desirable.

3. No significant skin irritation has been seen during 2 years of observations on animals treated with back rubbers.

4. DDT residues in fat of cattle using back rubber units for an entire season averaged 1.8 p.p.m., with a maximum of 5.2 p.p.m. Animals sprayed 3 times with 0.5 per cent DDT averaged 14.9 p.p.m. or over 8 times the level found in cattle using the back rubbers.[1]

[1] The help of P. Kohler, W. Berndt, and J. Lofgren in assembling entomological data, O. McKinney, O. Olson, and R. Pengra in conducting chemical analyses, and Drs. G. S. Harshfield, D.V.M. and I. H. Roberts, D.V.M. in evaluating skin lesions is gratefully acknowledged.

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ANNOUNCING

The Society of Systematic Zoology will initiate publication this spring of a new quarterly journal, SYSTEMATIC ZOOLOGY. The first number is scheduled to appear in March. Articles of general interest to all zoological systematists will occupy most of the space in the journal. Book notices, news items, projects, people, museum activities, lists of systematic societies, and other miscellany will round out the contents.

Occupying a hitherto conspicuous void in the coverage of zoological fields by scientific journals, the new serial has three purposes: "(1) to publish, and therefore to encourage the preparation of, contributions on basic aspects of all fields of systematic principles and problems; (2) to provide a suitable forum for discussion of the problems of the systematist and his methods; and (3) to report the other activities of the Society of Systematic Zoology as news."

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Insect Transmission of Yellow Leaf Roll Virus of Peach

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Yellow leaf roll, a virus disease of peaches, occurs in the "peach bowl" area of California where its known distribution is limited to portions of Yuba, Sutter, Butte and Placer Counties. The disease, discovered in 1950, was described by Nyland & Schlocker (1951) who transmitted the virus experimentally by means of grafting.

The present paper reports experiments, conducted at the University of California, demonstrating that the geminate leafhopper, *Colladonus geminatus* (Van D.), is a vector of yellow leaf roll virus. This species has been shown previously to transmit California aster yellows virus (Severin 1934) and western X-disease virus (Wolfe *et al.* 1950).

Although over fifty virus diseases have been described from stone fruits, insect vectors have been reported for only a few of them. Those with previously known vectors are: peach yellows (Kunkel, 1933), phony peach (Turner 1949), western X-disease (Wolfe *et al.* 1950; Anthon & Wolfe 1951), and wilt and decline of cherries (Kaloostian *et al.* 1951). Except for cherry wilt, transmitted by the black cherry aphid, *Myzus cerasi* (F.), all known vectors of stone fruit viruses are leafhoppers. It will be noted that except for work on peach yellows, all publications on vectors of stone fruit viruses have appeared in the last 4 years.

Procedure.—The test insects were reared in the greenhouse on celery or on peach. *Colladonus geminatus* readily completes its life cycle on peach, but good populations can be maintained more easily on celery. The feeding time of the test insects on inoculum varied from 5 to 34 days. In some instances the leafhoppers hatched from eggs deposited in the leaves of diseased plants. The leafhoppers were left on the test plants from 7 to 90 days.

The yellow leaf roll plants used as the virus source in these tests were Lovell or Gaume peach seedlings grown in the greenhouse and infected either by means of bud grafts or by infective insect vectors.

All test plants were Lovell peach seedlings germinated in the greenhouse ater 3 months of dormancy at 36° F. At the time of exposure to the test insects, the trees were growing in 6 inch pots and were approximately 12 inches tall. Over 100 peach trees held as controls have remained free of the disease.

Results.—*Symptoms.* The first symptoms of the disease appeared in the test plants 6 weeks to 4 months after exposure to infective insects. The longer incubation periods occurred in plants making slow growth.

Early symptoms include rolling of the leaves with some clearing of the veins followed by a lighter green color of the leaf blade. Soon thereafter, the leaves acquire more yellowish color and, later in the season, the veins become swollen. Leaf tissue may also become necrotic and drop out, leaving a ragged appearance. Diseased branches drop their leaves prematurely, except for the terminal leaves which sometimes remain green.

Vector Tests. Greenhouse tests with *Colladonus geminatus*, initiated between December 1950 and October 1951, have resulted in a total of 31 positive cases of transmission to date.

The geminate leafhopper apparently transmits yellow leaf roll virus with good efficiency compared to other known leafhopper transmitted viruses of stone fruits. In one series of 32 tests in which the number of insects per tree varied from 5 to 20 nymphs and adults, 19 cases of transmission resulted. Moreover, in the six tests involving 20 nymphs per tree, five out of the six tests were positive.

Yellow leaf roll virus undergoes a long latent period in the body of its vector and it is retained by the leafhopper for an indefinite period of time. Table 1 shows the results of a test in which groups of insects were transferred at approximately weekly intervals to healthy peach trees after an initial period of 5 days on the inoculum. In this preliminary experiment the minimum latent period was not demonstrated precisely, but the extremes possible for the latent period in the infective individual or individuals of group number 5 are 21 and 34 days. The fact that the latent period in all other groups as 34 days

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Table 1.—Transmission of yellow leaf roll virus of peach by *Colladonus geminatus* in serial transfers, demonstrating latent period and retention of the virus in the vector. Insects were on the diseased tree for 5 days before transfer to the first healthy plant.

Test Tree No.	Elapsed Time in Days Between 1st Day on Inoculum & 1st Day on Respective Test Plants	Insects Groups Tested[1]											Average No. Surviving Insects Transferred to Test Trees
		1	2	3	4	5	6	7	8	9	10	11	
1	5	−[2]	−	−	−	−	−	−	−	−	−	−	15
2	17	−	−	−	−	−	−	−	−	−	−	−	8.4
3	25	−	−	−	−	+	−	−	−	−	−	−	4.6
4	34	−	−	−	−	+	−	−	−	+	−	−	3.3
5	41	−	+	−	+	−	+	−	−	+	−	+	2.7
6	52	−	+	−	−	−	+	−	−	+	−	+	2.1
7	65					−					−		2.0

[1] Groups 1 to 9 each started as 15 nymphs, groups 10 and 11 as 15 adults.
[2] The minus sign (−) indicates lack of virus transmission, and the plus sign (+) indicates production of the disease.

or longer makes it probable that in group 5 this period was not under 25 days.

The geminate leafhopper is a common species in the fruit-growing areas of California and other western states. However, it may be that it is not the most important insect vector of yellow leaf roll virus in California. A related species, *Colladonus montanus* (Van Duzee), is much more abundant in the disease area. *Colladonus montanus* has not yet been demonstrated to transmit the virus, but adequate tests involving this species have not yet been completed.

Exploratory tests involving Fulgoridae, Membracidae and 14 genera of leafhoppers, other than *Colladonus*, have been negative.

Colladonus geminatus is known to be a vector of California aster yellows virus (Severin 1934). Moreover, the main vector of aster yellows, *Macrosteles divisus* (Uhler), occurs very commonly in the yellow leaf roll area. Attempts were therefore made to transmit this virus from aster to peach by *Macrosteles divisus* and from celery to peach by *Colladonus geminatus*. No infection was obtained in peach. These tests were made to establish if peach is susceptible to aster yellows virus and, if susceptible, to determine what, if any, similarity the disease in peach might have with yellow leaf roll of peach.

Discussion.—The identity and relationships of yellow leaf roll virus are still not well known, but this disorder has some characteristics which indicate that it is caused by a virus closely related to, or which is a strain in the polymorphic western X-disease complex. Although typical symptoms of yellow leaf roll and western X-disease are readily distinguishable they do have symptoms in common and trees are found having symptoms intermediate between the two typical forms (Schlocker & Nyland 1951).

The first insect vector demonstrated for western X-disease virus was the geminate leafhopper (Wolfe *et al.*, 1950) which also transmits yellow leaf roll virus. Moreover, the latent period of western X-virus in *Colladonus geminatus* was shown by Wolfe *et al.* (1951) to be a month or more, which seems to agree closely with the latent period of yellow leaf roll virus in the same vector species.

Thus, the fact that yellow leaf roll and western X-disease have symptom similarity and at least one insect vector species in common suggests that the causal viruses are closely related. However, there are distinctions which, from a practical standpoint, are very important.

In addition to differences in symptoms, yellow leaf roll affects peach trees more severely than does western X-disease. The disease also spreads more rapidly and more completely throughout affected trees than is usually true for western X-disease.

Both diseases occur in the same area, but the incidence of spread from tree to tree is much more rapid for yellow leaf roll than for western X-disease. In fact, the increased spread and severity are so alarming that the California Department of Agriculture is attempting to remove all

yellow leaf roll trees as soon as they are discovered. Schlocker (1951) reported that during 1951, inspections were made of 3,391,424 separate peach trees. In addition, second, third and fourth inspections were made in the main disease areas. In 1950, when the disease was discovered, 877 infected trees were found. In 1951 an additional 1,029 new cases were found which had not showed evident symptoms in 1950 (Schlocker 1951).

The more rapid spread of yellow leaf roll disease in the orchards may be due to differences in population density of the important vectors if more than one species is involved in spreading yellow leaf roll (at present an unknown factor) and to differences in the efficiency with which vectors, common to both diseases, transmit the two viruses. Tests conducted thus far indicate that *Colladonus geminatus* transmits yellow leaf roll virus much more efficiently than it does the California buckskin form of western X-disease. It may be that yellow leaf roll virus is more consistently available to the vector in diseased trees than is California buckskin virus.

SUMMARY.—Yellow leaf roll, a serious virus disease of peaches in northern California, has been transmitted experimentally by the geminate leafhopper, *Colladonus geminatus* (Van Duzee). This leafhopper species is common in stone fruit orchards of western United States. It is able to live on peach for extended periods of time and will complete its life cycle on this host if confined to it in cages.

The virus has a long latent period in the insect vector, typically more than a month. Thereafter, the leafhopper may retain the virus for extended periods of time and infect several trees in succession.

Yellow leaf roll, now known only from a limited area in California, is similar in some of its symptoms to the widely distributed western X-disease of peach which also occurs in the same locality. The fact that *Colladonus geminatus* is a vector of both diseases lends support to the belief that they are caused by closely related viruses. However, yellow leaf roll is a more severe disease, invades infected trees more rapidly and spreads from tree to tree faster in California than does western X-disease.

Colladonus geminatus is one of the few leafhopper species known to transmit more than one virus. It is a known vector of California aster yellows virus in addition to transmitting the viruses causing western X-disease and yellow leaf roll of peach.

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SCIENTIFIC NOTES

Ectoparasitism of Norway Rats in an Inland New England Village and in a New England Seaport

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Ectoparasitism of rats has been investigated in many southern coastal cities and western cities because of possible introduction, and in the past actual cases, of plague, as well as in many southern inland localities because of the presence of murine typhus. However, there are very few data from small population centers in the northeastern states. Only two studies are known to have been made in New England, both involving large seaport cities: Robinson (1913) in Providence, and Fox & Sullivan (1925) in Boston. The collections reported herein are from the small inland New England village of Kingston, Rhode Island, which has a resident population of about 500 and an additional 2000 university students. It has practically no business establishments, is located 6 miles from the sea coast, and 25 miles from Providence, the nearest seaport.

Norway rats, *Rattus norvegicus* (Erxl.), were trapped alive in steel traps, collected in rat bags, killed with chloroform, and then carefully combed and inspected for all parasites. Fifty-four rats were collected at the rate of about two each week between October 12, 1950, and May 2, 1951. About 82 per cent were adults and 18 per cent immature. Although this number of collections appears small at first glance, it probably included at that time about 10 to 25 per cent of the entire rat population. Furthermore, the village covers only about 0.5 square mile of a rather uniform habitat. Thus this sample probably was as representative of the rat population as one involving many hundreds of rat collections in a large city with diversified habitats. Collections totaled ninety-two fleas, 222 mites, and 1378 lice. Samples of identified ectoparasites were sent to Dr. Harry D. Pratt of the Communicable Disease Center, U. S. Public Health Service, Atlanta, who found the determinations to be correct.

Robinson's (1913) study in Providence, a large industrialized, seaport city, offers limited opportunity for comparison with collections in Kingston, a small, non-industrial, inland village. Although Robinson's study was made some years previously, Providence is an old city and it is likely that factors governing the rat ectoparasite population have not changed significantly. An aberrant factor in comparison is that the Providence survey covered July 18 to the end of December while the present collections covered October 12 to May 2. Fortunately, however, cold weather arrived late in 1950 and the October collections probably represent to some extent the late summer conditions. Comparison of overlapping collecting periods is not possible because Robinson did not divide his data on a seasonal basis except to state that the average number of fleas per rat was 10.2 from July 18 to September and 3.7 from October through December. This difference in numbers probably resulted from seasonal fluctuations in population levels as well as the fact that the survey was confined to the water front from July 18 through September, while it covered the whole city, including the water front, from October through December. Robinson's data included 341 rats; 59 per cent were adults and 41 per cent immature.

The native northern rat flea, *Nosopsyllus fasciatus* (Bosc.), was the predominant species taken in Kingston. It occurred on 41 per cent of the rats, averaged more than one specimen per rat, and nearly four per rat of those rats infested with fleas. It comprised 85 per cent of the fleas in the Kingston collections but only 22 per cent of the Providence collections.

Xenopsylla cheopis (Roths.) was not taken in Kingston. It is not known whether this indicates that the species was absent, because of Kingston's inland position with the resulting difficulty of introduction or for other reasons, or whether very limited numbers may have occurred during the summer but were not present on the rats when collected. Further evidence of its scarcity or absence is shown in that no *X. cheopis* are present in the 25 collections made from rats by Dr. John Barlow at various times during the summer and fall of 1914. In contrast, 75 per cent of the fleas taken in Providence was *X. cheopis*. The abundance of this species accounted for the over-all greater abundance of fleas in Providence as compared to Kingston.

The remaining three species of fleas occurred in small numbers. *Leptopsylla segnis* (Schön.) comprised 2.5 per cent of the fleas in Providence and was not taken in Kingston; it is normally a rat parasite while the other two species are facultative. Rural influence is shown by *Ctenophthalmus pseudagyrtes* (Baker), a mole flea, comprising the remaining 15 per cent of the Kingston collections. Robinson found 0.5 per cent of the fleas in Providence to be *Ctenocephalides canis* (Curtis).

At Kingston, 48 per cent of the rats were infested with fleas, averaging two per rat and four per infested rat; in Providence the average was 6 per rat and 11 per infested rat.

A mite, *Haemolaelaps glasgowi* (Ewing), comprised 93 per cent of all mite collections, and infested 30 per cent of the rats, with an average of 4 per rat and 13 per infested rat; the remaining 7 per cent consisted of *Eulaelaps stabularis* (Koch) which infested 11 per cent of the rats at the rate of 0.3 per rat and 2 per infested rat. Thirty-seven per cent of the rats were infested with mites, averaging 4 per rat and 11 per infested rat. On the other hand, Providence collections were entirely *Echinolaelaps echidninus* (Berl.) with 21 per cent of the rats infested.

A louse, *Polyplax spinulosa* (Burm.), was the only louse taken either in Kingston or Providence. It infested 81 per cent of the rats taken in Kingston and 24 per cent in Providence. In Kingston the average per rat was 25, and 31 per infested rat.

In the Kingston collections, no parasites were taken on 11 per cent of the rats. Four per cent had all five species of parasites. About 30 per cent had lice but no fleas or mites. Lice and mites, but no fleas, occurred on 8 per cent. Lice and fleas, but no mites, were present on 18 per cent. All rats with fleas and mites also had lice. Fleas, lice, and mites, one species or another, occurred together on 26 per cent. Maximum collections on a single rat, and date, were

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as follows: *Nosopsyllus fasciatus*, eight specimens on February 27; *C. pseudagyrtes*, two specimens November 18 and December 1; *Haemolaelaps glasgowi*, 90 specimens on January 5; and *Polyplax spinulosa*, 453 specimens on February 20. The *P. spinulosa* ratio of adults to immatures was 3.5 to 1.

SUMMARY.—Ectoparasitism data in the small inland village of Kingston, R. I., were obtained and limited comparison made with studies by Robinson in the large coastal city of Providence.

In Kingston, *Nosopsyllus fasciatus* constituted 85 per cent of the flea population. It infested 41 per cent of the rats, averaging more than one per rat and four per infested rat. *Xenopsylla cheopis* was not taken in Kingston but made up 75 per cent of the Providence population. *C. pseudagyrtes* constituted the remaining 15 per cent of the Kingston population.

Haemolaelaps glasgowi constituted 93 per cent of the Kingston mite population. It infested 30 per cent of the rats, averaging four per rat and thirteen per infested rat. The remaining 7 per cent was *Eulaelaps stabularis* which infested 11 per cent of the rats. Thirty-seven per cent of the rats were mite-infested. Providence collections were virtually all *E. echidninus*, infesting 21 per cent of the rats.

Polyplax spinulosa was the only louse in both the Kingston and Providence collections. In Kingston it infested 81 per cent of the rats, averaging 25 per rat and 31 per infested rat. It infested 24 per cent of the rats in Providence.

Certain data on combinations of the various species on individual hosts and maximum parasitism counts are given.

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Conversion of Per-Acre Dosages of Soil Insecticide to Equivalents for Small Units

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In laboratory and greenhouse experiments with soil insecticides, various methods have been used for converting pounds per acre to equivalent dosages for small units of soil for use in pots. For the convenience of workers computing dosages on an area basis, Nelson (1940) gave procedures for converting the quantity of insecticide applied per acre to that required to treat 1 square foot. A method commonly used in fertilizer experiments and in some entomological experiments is based on the assumption that an acre of air-dried soil to plow depth (6 to 6.66 inches) weighs 2,000,000 pounds. For insecticide experiments it seems desirable to make the conversions on a weight-per-volume basis, a method adopted by certain investigators of soil pesticides (Fleming & Maines 1947, Godfrey *et al.* 1934). Therefore, in this paper a table is given for use in converting pounds per 6-inch acre to equivalent dosages for various volumes of soil in pots and other containers of various sizes.

In recent studies the writer has found that with certain organic phosphorus compounds and other systemic chemicals applied to the soil, the margin of safety is narrow between dosages that are toxic to aphids and spider mites and those causing injury to the host plant. Applications of a chemical such as octamethyl pyrophosphoramide to plants growing in three types of clay pots, all of the same diameter but varying in depth and soil content, caused different degrees of plant injury and insect mortality when dosages were based on surface area. In other tests the same dosage of parathion that Granger and Leiby (1949) applied without injury to weighed air-dried soil at Ithaca, N. Y., caused serious injury when applied to plants growing in the same weight of local soil at Beltsville, Md. However, when the dosages of octamethyl pyrophosphoramide and parathion were based on the volume of the pots, the plant injury and the insect mortality in the different pots were comparable.

Air-dried soils vary considerably in their specific gravity—i.e., 1 gallon of silt loam weighs about 8 pounds, of sandy soil about 9.5 pounds, and of peaty soils about 3.2 pounds. Furthermore, the physical and chemical reactions in the soils are affected by the proportions of clay, sand, and organic matter, as well as by the acidity. Chemicals are more reactive in sandy soils than in clay soils or those of high organic content. These differences are explained, at least in part, by Bear (1942), who states that colloidal materials in soil serve as buffering agents to both acid and basic ions; also that organic colloids are nearly 10 times as effective buffers as is inorganic colloidal matter.

The roots of plants growing for a few weeks in clay pots or other containers will usually penetrate to all parts of the container. All the soil is utilized and plants growing in deep pots thrive for a longer time than those in shallow ones. Because the relationship between soil volume and surface area varies, it appears that chemicals should be applied at dosages based on volume rather than on the surface area or dry weight of the soil. The soil type and its other pertinent characteristics should be taken into consideration.

To determine the equivalent dosages of insecticides for various volumes of soil, it was first necessary to calculate the weight in milligrams per cubic centimeter that was equivalent to 1 pound per acre to a depth of 6 inches. With this factor, which was found to be 0.000735463 mg. per cubic centimeter,

Table 1.—Milligrams equivalent to 1 pound per 6-inch acre in various soil units.

SOIL UNIT	CC. OF SOIL	EQUIVALENT MILLIGRAMS PER UNIT
Standard pots:		
3-inch	180	0.132
4-inch	500	.368
5-inch	900	.662
6-inch	1,500	1.103
7-inch	2,400	1.765
8-inch	3,785	2.784
Short pot, 8-inch	2,900	2.133
Pan, 8-inch	1,400	1.030
Liter	1,000	.735
Gallon	3,785	2.784
Cubic foot	28,317	20.826
Bushel	35,238	25.916

the equivalent milligrams for various soil units were calculated, as shown in table 1. For example, for the 3-inch pot, which holds 180 cc. of soil:

$$180 \times 0.000735463 = 0.132 + \text{mg.}$$

It is suggested that these quantities of toxicant can be obtained most conveniently by diluting to 0.1-per cent strength and weighing in grams rather than milligrams, since 1 gram of 0.1-per cent material contains 1 mg. of toxicant. For example, 0.132 grams of a 0.1-per cent solution or dust contains 0.132 mg. of toxicant.

Values for multiples of these dosages or other concentrations of solutions or dust mixture may be readily computed from those given in the table. For solutions containing water as the diluent, milliliters may be substituted for grams. When a powdered insecticide is to be incorporated in a measured quantity of potting soil, the desired quantity is first dispersed in a small amount of finely sifted soil, which is then mixed through the entire batch.

Equivalents on the basis of a soil depth of $6\frac{2}{3}$ inches may be computed by multiplying by 0.9, the ratio of 6 to $6\frac{2}{3}$, or of a soil depth of 3 inches by multiplying by 2.

The clay pots used in obtaining these measurements were procured from a local manufacturer. Their capacities were based on the quantity of soil required to fill the pots to whithin 1 inch of the top, or approximately that followed in general greenhouse practices. Pots from other sources may differ in size and volume from those used in the present measurements. In any experiment each lot of pots should be selected for uniformity, and tables for determining dosages should be constructed on the basis of their volumes of soil as ordinarily filled for growing plants.

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The Value of Some Organic Phosphate Insecticides in Control of Grape Mealybug[1]

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The grape mealybug, *Pseudococcus maritimus* (Ehrhorn), appeared in large numbers in some vineyards in the lower Yakima Valley in the summer of 1950. The infestation apparently was not new because several growers stated that they had seen the honeydew on the grapes for a number of years previous to 1950, but in smaller quantities. The use of 5 per cent DDT dust for the control of the grape leafhopper, *Erythroneura comes* (Say), is not the sole cause of the sudden increase of the infestation. Some of the vineyards with the greatest number of mealybugs had no previous record of dust applications.

The infestation was brought to the writer's attention in late August, 1950. Immediate control was out of the question because the grapes already were heavily covered with honeydew and the majority of the adult females had migrated down to the trunks and main laterals where they were constructing "nests" under loose bark and depositing eggs. The eggs soon hatched and the crawlers overwintered under the loose bark, usually in the nests.

The presence of the grape mealybug on the grapes is objectionable from a number of aspects. In the first place, the clear, shining, sticky droplets of honeydew detract from the appearance of the fruit on the fresh market. The large quantities of honeydew that can be deposited, even by moderately light infestations, interfere with the picking operations because of the stickiness. The processors object primarily to the sooty mold that so readily grows on the honeydew.

MATERIALS.—Neiswander (1949) obtained excellent control with both lauryl thiocyanate (no longer available) and parathion. Because many of the mealybugs are partially protected from insecticides either by their waxy covering or because of their being located under loose bark at the time of application, insecticides having some fumigant, as well as contact action, were indicated. Several of the organic phosphates, therefore, were put on trial. These were parathion, 25 per cent wettable powder; a proprietary compound,[3] 27 per cent wettable powder; a second proprietary compound 4049,[4] 25 per cent wettable powder; and 2 per cent parathion dust. To each 100 gallons of spray material, 4 ounces detergent[5] was added to aid in wetting the mealybugs and to aid in penetrating under the bark.

PROCEDURE.—The mealybugs of the first generation were one-fourth to one-half grown on May 8, 1951. Control measures were delayed because of the very late bloom. During May and June the first generation matured and deposited eggs. By July 5 there were many groups of crawlers under the loose bark of 1- and 2-year old wood. On July 18 there were fewer groups, as the young mealybugs were dispersing over the vines. Most of the mealybugs were one-fourth grown on July 26, although some were still in the crawler stage and a few were about one-half grown.

On July 26 the infestation was clearly evident by the small amounts of honeydew recently deposited on the fruit. Although some mealybugs were still under the loose bark of 1- and 2-year old wood, most had moved to the bunches of grapes. Treatments were applied on July 27 while the amount of honeydew on the fruit was very small.

By examining the fruit for honeydew on July 26, the infestation was found to be general. Five rows were chosen, each protected by a buffer row from other treated rows. These were divided into three

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[3] (EPN) Ethyl *p*-nitrophenyl thionobenzenephosphonate. E. I. Du Pont de Nemours and Co.

[4] S-(1, 2-dicarbethoxyethyl) 0, 0-dimethyl dithiophosphate. American Cyanamid Co.

[5] Sodium lauryl sulphate (*Dreft*) Procter and Gamble

Table 1.—Bunches of grapes with honeydew and number of mealybugs on 120 bunches, Grandview, Wash.

Material and Concentration	August 3, 1951, 14 Days After		August 21, 1951, 25 Days After		September 13, 48 Days After	
	Clusters	Mealybugs	Clusters	Mealybugs	Clusters	Mealybugs
1 lb. 25% parathion per 100 gal.	2	0	4	0	0	0
1 lb. 27% EPN per 100 gal.	45	29	46	18	30	0
1 lb. 25% 4049 per 100 gal.	10	4	23	11	28	0
50 lb. 2% parathion dust per acre	85	22	76	12	43	0
Untreated	109	184	118	595	109	15

sections, each 64 feet in length and containing 8 vines. This area was laid out in a randomized block design of five treatments and three replications of each treatment. Only the four center vines in each plot were used in evaluating the results. Ten bunches of grapes were chosen at random from each vine for making the counts of honeydew and mealybugs.

Sprays were applied with a high pressure sprayer having 500 PSI at the pump and using 200 feet of hose. The vines were throughly soaked from both sides. The dust was applied with a hand duster[4] at about 50 pounds per acre. Each vine was dusted from both sides.

RESULTS.—Parathion gave the best control (Table 1). Proprietary compound 4049 gave good early control but failed to hold the infestation down for the whole season. The other proprietary,[1] while giving poor initial kill, appeared to have sufficient residual action to maintain a moderately low infestation.

The greatest number of mealybugs was on the vines about August 21. After that time great numbers migrated to the trunks and main laterals. The reduction in numbers of bunches of grapes having honeydew on them on September 13 was due to the drying up of the small deposits. By September 13 there had been an increase in honeydew on grapes treated with 4049. No increases occurred on other treatments. The fruit was harvested on September 27.

As a further check on the degree of control obtained and as a possible indication of next year's control, two 1″ by 12″ strips of bark were taken from each vine previously used for the honeydew and mealybug counts. The numbers of current-season egg nests—*i.e.*, those containing unhatched eggs—were counted (Table 2). The results closely parallel those given in table 1. The data suggest that there will be no infestation in the parathion plots in 1952.

DISCUSSION.—The temperature was 95° F. at time of application. Maximum temperatures between 91° F. and 96° F. prevailed for the following 9 days. No visible damage to the vines or fruit resulted from any of the materials used.

The odor of the compound 4049 was strong for 14 days following application and faint for 4 days more. No odor was noticeable in the parathion rows 7 days following application.

SUMMARY.—One thorough spray of 1 pound of 25 per cent parathion gave excellent control when applied at the time the second generation mealybugs were beginning to deposit honeydew on the fruit. No honeydew could be found on the fruit 48 days following application, nor at harvest time 62 days later. No egg masses were found under the bark of the parathion-sprayed vines, indicating a second year's control. The experimental p-nitrophenyl compound gave poor initial control but had a better residual action than compound 4049. Two per cent parathion dust gave poor control.

Table 2.—Total number of current-season egg nests on 24, 1 by 12 inch, strips of bark from the trunks, Grandview, Washington.

Material per 100 Gals.	After 69 Days
1 lb. 25% parathion per 100 gal.	0
1 lb. 27% EPN per 100 gal.	19
1 lb. 25% 4049 per 100 gal.	25
50 lbs. 2% parathion dust per acre	39
Untreated	238

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[4] Root *Nap-sak* duster.

Effectiveness Against House Flies of Six Pyrethrum Synergists Alone and in Combination with Piperonyl Butoxide

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Pyrethrum synergists have been used for more than 10 years to extend the pyrethrum supply as well as to produce more effective formulations at lower cost. In view of the current shortage of pyrethrum and its high price, manufacturers are using large quantities of synergists and are extremely interested in pyrethrins-synergist combinations.

Piperonyl butoxide[1] is a well-known pyrethrum synergist, as demonstrated by the studies of Wachs (1947) and others. Tests have been conducted to determine if a combination of piperonyl butoxide with each of six commercial synergists at critical concentrations shows a greater toxicity to house flies than critical concentrations of the individual synergists used alone. The commercial synergists employed in combination with piperonyl butoxide

[1] Technical product containing 80% of pure compound (3,4-dioxymethylene-6-propylbenzyl) (butyl) diethyleneglycol ether.

Table 1.—Results of large-group Peet-Grady tests on house flies using six pyrethrum synergists alone and in combination with piperonyl butoxide.

	Spray Mg./100 Ml.	No. Tests	No. Cultures	10 Min. % KD	24 Hrs. % Dead	Plus Value on Basis 50 Mg. Pyrethrins
	Series 1					
1.	O.T.I.	4	3	98.5	50.4	—
2.	50 Pyrethrins	4	3	95.5	24.1	—
3.	50 Pyrethrins 25 Pip. Butoxide	4	3	96.5	61.0	36.9
4.	50 Pyrethrins 25 Sulfoxide	4	3	93.5	57.6	33.5
5.	50 Pyrethrins 12.25 Pip. Butoxide 12.25 Sulfoxide	4	3	97.9	63.2	39.1
	L.S.D. 5% 9.0 L.S.D. 1% 13.7					
	Series 2					
6.	50 Pyrethrins	12	6	94.4	19.8	—
7.	50 Pyrethrins 25 Pip. Butoxide	12	6	98.0	61.7	41.9
8.	50 Pyrethrins 2000 264	12	6	98.5	66.7	46.9
9.	50 Pyrethrins 12.25 Pip. Butoxide 1000 264	12	6	98.3	74.1	54.3
	L.S.D. 5% 9.3 L.S.D. 1% 12.7					
	Series 3					
10.	50 Pyrethrins	4	2	95.9	18.7	—
11.	50 Pyrethrins 25 Pip. Butoxide	4	2	98.2	62.7	44.0
12.	50 Pyrethrins 200 Isome	4	2	98.1	69.2	50.5
13.	50 Pyrethrins 12.5 Pip. Butoxide 100 Isome	4	2	98.9	70.3	51.6
	L.S.D. 5% 3.8 L.S.D. 1% 5.7					
	Series 4					
14.	50 Pyrethrins	4	2	92.9	14.0	—
15.	50 Pyrethrins 25 Pip. Butoxide	4	2	97.3	55.8	41.8
16.	50 Pyrethrins 400 Sesame Oil Extractives	4	2	97.1	58.1	44.1
17.	50 Pyrethrins 12.5 Pip. Butoxide 150 Sesame Oil Extractives	4	2	96.6	58.9	44 9
	L.S.D. 5% 8.1 L.S.D. 1% 12.3					
	Series 5					
18.	50 Pyrethrins	4	2	93.3	13.0	—
19.	50 Pyrethrins 25 Pip. Butoxide	4	2	95.3	51.6	38.6
20.	50 Pyrethrins 500 I.N. 930	4	2	97.4	53.2	40.2
21.	50 Pyrethrins 12.5 Pip. Butoxide 250 I.N. 930	4	2	97.4	54.8	41.8
	L.S.D. 5% 5.5			L.S.D. 1% 8.4		

	Spray Mg./100 Ml.		No. Tests	No. Cultures	10 Min. % KD	24 Hrs. % Dead	Plus Value on Basis 50 Mg. Pyrethrins
			Series 6				
22.	50	Pyrethrins	4	2	96.8	17.8	—
23.	50	Pyrethrins	4	2	98.9	65.5	47.7
	25	Pip. Butoxide				[redacted]	
24.	50	Pyrethrins	4	2	97.8	64.9	47.1
	50	Pip. Cyclonene					
25.	50	Pyrethrins	4	2	99.0	65.0	47.2
	12.5	Pip. Butoxide					
	25	Pip. Cyclonene					
	L.S.D. 5% 8.6			L.S.D. 1% 13.0			

were 264,[1] sulfoxide,[2] n-propyl isome,[3] sesame oil extractives,[4] I.N. 930,[5] and piperonyl cyclonene.[6]

The large-group Peet-Grady Method (Anon. 1951), which employs approximately 500 flies per test, was used to evaluate the synergist combinations. The flies employed in these tests were the CSMA[7] 1948 strain (nonresistant) with an approximately 50-50 sex ratio. Adult flies received a diet of 5 per cent spray-dried nonfat milk solids in water during the aging period prior to testing. The synergists were used at previously determined levels that resulted in a mortality at 24 hours of approximately 70 per cent or less.

All tests within a given series were conducted on the same fly cultures, and best comparisons are consequently made within a series rather than between series.

Because of technique difficulties, base oil (a typical odorless-type household insecticide base oil, 0.78 sp. gr. and 380 to 480° F. boiling range and base oil-synergist combinations were not included among the test sprays. Previous tests indicated extremely low base oil mortalities which were not appreciably increased by the presence of the synergists used at the critical concentrations employed in the tests.

Data are given in table 1.

From the results of these tests, we can conclude that a combination of piperonyl butoxide and the above synergists at critical concentration levels showed for the most part only an additive effect; there was no evidence of inhibition or hypersynergism of economic importance. Piperonyl butoxide, sulfoxide, and piperonyl cyclonene on a weight basis were the most efficient pyrethrum synergists for house fly control used in these tests.

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[1] Technical product containing 98% of pure compound n-octyl bicycloheptene dicarboximide.
[2] n-Octyl sulfoxide of isosafrole.
[3] Condensation product of n-propyl maleate with isosafrole.
[4] 20% sesame oil extractives concentrate (including 3.34% sesamin).
[5] Isobutyl undecylenamide.
[6] Condensation product of the alkyl-3,4-dioxymethylenestyryl ketones with ethyl acetoacetate.
[7] Chemical Specialities Manufacturers Association.

Biological Control of *Planococcus citri* on Commercial Greenhouse *Stephanotis*

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Under greenhouse conditions the commercially grown *Stephanotis* is a vigorous climber and is trained on a supporting framework of wire. The intertwining vines not only offer many protective niches for the citrus mealybug, *Planococcus citri* (Risso), but make the control of these insects by syringing or the application of insecticides a difficult problem. During 1951 an experiment was conducted to test the effectiveness of biological control of *P. citri* under these conditions.

In the greenhouse where this investigation was undertaken the cultural practices on *Stephanotis* were as follows: The greenhouse was not heated and the top vents were left open during December for the purpose of hardening the plants. In January after the plants had been pruned back severely the house was closed and held at a relatively high temperature (seldom dropping below 70° F.). This forced a rapid growth of the plants and brought the peak of blossom production in coincidence with the best market demand during May and June. As a normal practice the grower applied insecticides for mealybug control at least three times during the year, but since he had suffered some plant injury during the previous season he wished to employ biological control during 1951 and agreed to withhold all insecticidal treatment. These conditions were maintained and proved to be ideal for the effective use of two mealybug enemies, an encyrtid parasite, *Leptomastix dactylopii* (Howard), and the coccinellid predator, *Cryptolaemus montrouzieri* Mulsant.

Previous studies on the biological control of *Planococcus citri* (Risso) in gardenia ranges (Doutt 1951) showed that this control method can be very effective if temperatures do not drop below the minimum activity threshold for *Cryptolaemus*, which is reported to be 70° F. (Smith & Armitage (1931)). Although no such careful studies have been made on the influence of temperature on the activities of *Leptomastix dactylopii*, the insect was originally imported from Brazil and seems to prefer a warm humid environment. The conditions under which *Stephanotis* are cultured are thus optimum for both of these natural enemies of the citrus mealybug, and the efficiency of their activities is manifested in the results obtained.

Table 1.—Degree of infestation of greenhouse *Stephanotis* by citrus mealybug, *Planococcus citri* (Risso).

DATE	PER CENT PLANTS INFESTED
December	43
January	66
April	1
May	0
June	0
July	0
August	0
September	1
October	2

At the outset a survey was made of each of 528 *Stephanotis* plants in the greenhouse to ascertain the degree of mealybug infestation. When even a single mealybug was found, the plant bearing it was designated as infested, and this classification was used during repeated inspections throughout the season as a basis for measuring the effectiveness of the natural enemies in reducing the pest population. At the beginning of the experiment the infestation of mealybugs was quite heavy and each infested plant had a high population of mealybugs in all stages of development. It is thus quite obvious that *complete eradication* of mealybugs on a plant was required before any decrease in the degree of infestation could appear in the sampling data. Therefore the criterion selected for evaluating this work demands an extraordinarily effective control before any change is reflected in the data, and this should serve to emphasize the impressive results that can be obtained through biological control.

After the greenhouse was closed and heated in January the release of natural enemies was begun. During the period extending from January to April a total of 19,360 *Leptomastix* and 600 *Cryptolaemus* were liberated in this greenhouse. From the data in table 1 it is evident that these insects were colonized on a rapidly expanding host population, nevertheless their combined effect was soon apparent. By April the mealybug infestation had been so markedly reduced that only 1 per cent of the plants remained infested, whereas 66 per cent had been infested in January. A 4-month period followed during which scarcely a single mealybug could be found on close inspection of each of the 528 plants. During this period the natural enemies were without hosts and gradually disappeared. However, the adult *Cryptolaemus* maintained themselves for a time after the disappearance of mealybugs by feeding on the immature stages of hemispherical scale, *Saissetia hemisphaerica* (Targioni). The light infestation of this scale was reduced by this feeding and by the activity of the parasite, *Metaphycus helvolus* (Compere).

In September a few mealybugs were again found in sampling and these may have been the result of an accidental introduction by greenhouse workers. The infestation slowly increased after September but remained well below an economic level, particularly since all mealybugs observed during September and October were single individuals on widely separated plants.

It is believed that these results as closely approach eradication of a pest as is possible by use of the biological control method. Eradication of a host by means of natural enemies is theoretically possible in a limited environment or at any point in space and time. Actually, eradication of *Planococcus citri* has frequently occurred in our laboratory in battery jar cultures of *Leptomastix* as well as in cultures of *Cryptolaemus*. The greenhouse population simply exhibited the same phenomenon on a larger scale.

Under the conditions existing during the course of this investigation it is apparent that biological control can be used very effectively in the control of mealybugs on commercially grown *Stephanotis*. The near eradication of the host followed by the disappearance of its natural enemies would seem to require an annual colonization of natural enemies in each greenhouse. The method is placed on a sound practical basis by the degree of control obtained at a low cost and without injury to the plants.

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Method for Isolating Males and Females in Laboratory Colonies of *Aëdes aegypti*

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In the course of some work on the yellow-fever mosquito, *Aëdes aegypti* (L.), the writers have found it necessary to separate large numbers of males from females of this insect. Pupae of both sexes are placed in beakers and adults are allowed to emerge in cages 9 by 10 by 13 inches. In removing the adult males, use is made of their response to certain sound frequencies. It has been shown (Roth 1948), that when a cage containing many males of *A. aegypti* is agitated to induce flight, and a tuning fork of the proper frequency is struck and held near the outside of the cage, the males are attracted in numbers to the sound source (*i.e.*, to the prongs of the vibrating tuning fork). The males, after being attracted, seize the cloth of the cage and vibrate their wings (Fig. 1). It is during this seizing response, while the males are concentrated in a relatively small area and clinging to the side of the cage, that they can be readily removed with a venturi-type aspirator (Peterson 1947), which is attached to a compressed air-line. By repeating the procedure of jarring the cage to induce the males to fly, striking the tuning fork (forks between 320 and 512 v.p.s. are effective), and removing the males that are attracted or clinging to the side of the cage, a large number of males may be collected and transferred to separate cages in a short period of time.

It is not known to what extent this technique may be applicable to other species of mosquitoes. Males of *Culex pipiens* and *Anopheles quadrimaculatus* respond to sound in a manner similar to *Aëdes aegypti;* however, the response is given only when the males of the former species are in a mating-state and this occurs only periodically (Roth 1948). The males of *A. albimanus* have been attacted by the

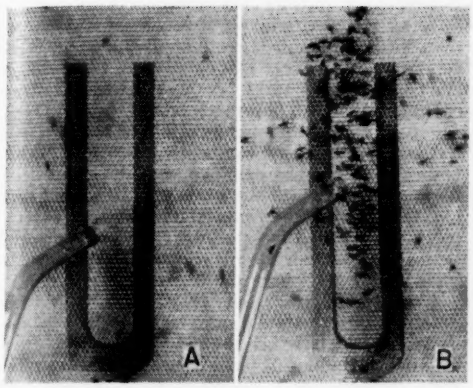

FIG. 1.—Attraction of *Aëdes aegypti* males in a cage 9 by 10 by 13 inches, to sound produced by a tuning fork (frequency: 480 vibrations per second). A—Distribution of mosquitoes around tip of aspirator before sounding the tuning fork. B—Distribution of male mosquitoes a second or two after the tuning fork was sounded.

recorded sounds of females, in field tests (Kahn & Offenhauser 1949). Presumably a sounding tuning fork of the proper frequency might be used to concentrate males of any species of mosquito if they are attracted by sound while in a mating-state.

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Efficiency of Various Orchard Spray Machines

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Concentrate spraying is demanding more and more attention among Connecticut orchardists today. The reason—possible economies in view of low profits during the last few years. Also, pertinent is the fact that such machines lend themselves readily to one-man operation thereby allowing the owner of a small orchard to do the spraying himself and making him more independent of labor.

New sprayers sell from $1000 to $4500, at least those suitable for an orchard of any size. Not many can afford the higher cost, but the efficiency of low or high priced machines is important under any condition. The following deals mainly with cost of application and very little with cost of materials.

DEPRECIATION.—Depreciation is an important item, though somewhat difficult to estimate. Who knows, for example, how long a machine will remain in operation? One can give an average life of 10 years, but some of the orchard sprayers of the past have been in operation 20 years for more. The newer air-blast sprayers have larger motors and high speed fans so, unless very sturdily built, will in all probability wear out sooner than the hydraulic or high pressure rigs. Again, if items such as pumps or fans have to be replaced frequently, or if there is an increase in repair bills over the older types, the original cost does not present a true base for estimating depreciation. In some of the smaller machines built to sell at a low figure, vibration is very great and as a result parts have broken or loosened after the machine has been in operation only a few hours. On the other hand, improvement in construction of orchard mist blowers during the last few years has

Table 1.—Cost of spraying an acre of apples, 1950.

MACHINE	DEPRECIATION	GAS AND LABOR	TOTALS PER ACRE
1	1.87	.53	2.40
2	1.41	.53	1.94
3	.93	1.32	2.25
4	.93	1.16	2.09
5	1.41	.97	2.38
6	1.87	1.01	2.88
7	1.41	.95	2.35

Assuming life of each machine to be 10 years.
Machines 1 to 6 are mist blowers.
No. 7 is a hydraulic 50 g.p.m. outfit.

Table 2.—Study of spray machines 1950–1951, showing acres sprayed per 8-hour day—per man and per machine and acres sprayed per fuel dollar.

MANUFACTURER AND TYPE OF EQUIPMENT	CONCENTRATION	PER FUEL DOLLAR	PER MAN	PER MACHINE
	Air Blast			
1. Blower attachment	(1×)	3.4	13.8	13.8
1. Fixed outlet, fixed vanes	(4×)	4.4	33.4	33.4
1. Fixed outlet, adjustable vanes	(4, 6×)	4.6	24.5	24.5
1. Fixed outlet, adjustable vanes	(4, 6×)	3.6	16.6	16.6
2. Flexible outlet	(4, 6×)	5.7	8.5	17.0
2. Rotating outlet	(4, 6×)	2.6	19.5	19.5
2. Moveable outlet	(6×)	4.7	10.0	20.0
3. Oscillating outlet	(1×)	3.4	15.3	15.3
3. Fixed outlet	(2×)	4.4	14.4	28.8
3. Fixed outlet	(1×)	4.0	13.2	26.4
3. Fixed outlet	(1×)	2.5	18.4	18.4
3. Fixed outlet	(1×)	2.5	12.3	24.6
4. Fixed outlet	(1×)	3.2	16.1	16.1
	Averages	3.8	16.6	21.1
	Hydraulic[1]			
4. Broom	(1×)	9.0	10.0	20.0
4. Broom	(1×)	11.0	3.6	11.0
3. Broom	(1×)	3.6	16.0	16.0
2. Gun and broom	(1×)	3.7	3.6	11.0
2. Gun	(1×)	3.6	8.7	8.7
5. Oscillating boom	(1×)	3.9	17.0	17.0
	Averages	5.8	9.8	13.9

[1] All 35 to 50 gallon pumps.

[1] A. DeCaprio has been responsible for many of the observations reported in this paper.

been marked and we will doubtless have many excellent concentrate machines in a short time. Estimated on a 10-year life, depreciation of mist blowers in 1950 varied from 93 cents per acre sprayed to $1.87. Hydraulic depreciation came to $1.41 (Table 1).

FUEL CONSUMPTION.—Fuel is an important item, though frequently disregarded. We often hear the remark, "I don't care about the gasoline, if I can get along with less labor." As apparent in table 2, the amount of fuel used per acre may vary in Connecticut from 25 to 57 cents or may go as low as 11 cents for more efficient hydraulic sprayers. Much depends here on amounts applied per tree; speed of travel; number of separate machines required, including sprayer, tractor and blower, if separate, and whether some or all of the machines used for spraying or transportation are Diesel operated. Figures giving amounts used per day are often misleading because of the speed of coverage. Consequently, the acres covered per dollar spent for fuel is given in the table. For this purpose 30 trees, 20 to 25 feet high, are considered equal to an acre. Still another factor lies in the time of application since mid-season applications, when all foliage is out, will be somewhat slower than early season sprays requiring less material per tree. It will be noted, however, that the average figure shows more acres covered per fuel dollar for the hydraulics than for the air blast machines.

MAN POWER.—The spray crews observed in 1951 varied from one to three men. It would seem in view of the availability of modern equipment and the high cost of labor that the three-man crew is out of date. Nevertheless, there are some still in operation. We have also noticed a considerable difference in efficiency between operators, which is to be expected.

ACRES PER DAY.—Many factors affect the rate of coverage of which ground speed, concentration, location of the water supply and efficiency of the filling operation are most important. Thus, a tank may be sprayed out in 15 minutes and 15 minutes required for supply and refill. Such slow filling is no longer necessary in view of the current availability of small inexpensive high volume pumps. The greatest speed of refill seems to be from these high volume pumps or overhead tanks with large outlets. Three to 5 minutes for 500 gallons is about the least encountered. Another point lies in the use of wheel tractors versus the caterpillar. Travel back and forth with the wheel type is much more rapid than with the caterpillar and where the wheel type be used they greatly facilitate speed of operation. As already noted, however, the tanks sprayed per hour or gallons per hour, depends in part on the location of the water supply as well as the speed back and forth. Some operators depend on nurse tanks, which increases the rate of application but requires more man power. Sometimes loss of efficiency occurs here if the time to bring up a new load does not match the time needed to spray out one tank. It should be mentioned further that the coverages per day naturally depend on the length of the work day—whether 8, 10 or more hours. Some have claimed much higher acreages covered than indicated in the table and it may possibly be true, but the figures given are based mostly on our own field observations. It will be seen that the average number covered with air blast machines per 8-hour day is much greater than with the hydraulics.

MATERIALS USED.—Direct comparisons of mist blowers and hydraulics operating in the same orchard leads to the belief that it is easily possible to spray more material per acre with a mist-blower than with a hydraulic as commonly operated. Some types of nozzles wear readily so that the operator must keep alert if spray is not to be wasted. If we could get it, a good flow meter would be useful here. Air speed and pump pressure also have a bearing on the concentration that can be used, which so far has not exceeded five or six times normal in Connecticut. As for clogging, both size of nozzle orifice and type of spray material have important influences. Orifices much less than three sixty-fourths inch have not been too satisfactory, while the materials giving the most trouble have been sulfur pastes.

RESULTS.—Comparisons of controls with those obtained with hydraulic sprayers, indicate that just as good results have been obtained with mist blowers as with hydraulics in Connecticut. There has been some difficulty with tall trees 25 to 30 feet high especially since not all types available reach the tops and so both scab and codling moth develop. Those with air velocities above 125 miles per hour and those provided with adjustable vanes in the air slot have so far given satisfactory results. Automatic moveable outlets according to our observations have not been much of an improvement besides providing additional machinery to get out of order.

Comparison of Dieldrin and Aldrin with other Compounds as Grasshopper Toxins

CHARLES H. BRETT AND WILLIAM J. EITEL[1]

These tests are a continuation of a series to compare new insecticides as grasshopper toxins. Selections which proved to be effective are described. A number of other compounds were tested but showed such a low order of toxicity that they were not included. Since the effectiveness of aldrin and dieldrin are well known, they served as standards for comparison.

Test grasshoppers were collected in the field. It was not practical to obtain pure species cultures because of the number needed. Nymphs and adults of the differential grasshopper, *Melanoplus differentialis* (Thos.), predominated. Also included were nymphs and adults of a number of species of the genus, *Melanoplus*. These consisted mostly of *M. bivittatus* (Say), *M. femur-rubrum* (Deg.), and *M. mexicanus mexicanus* (Sauss.). Dusted grasshoppers were mostly adult *M. differentialis*. Laboratory methods (Brett *et al.* 1951) have been previously described.

A few cultures contained parasitized individuals. This resulted in some mortality in untreated groups. Because of this, Abbott's formula was used in determining the per cent effective control.

DIELDRIN and ALDRIN gave results consistent with previous tests. Both were very effective as external and internal poisons. Dieldrin was more toxic than aldrin. These insecticides are known to give good control in the field when used at the rate of about 0.25 pound per acre.

HEPTACHLOR showed an external and internal toxicity which compared favorably with aldrin.

TM-1[2] was very toxic to grasshoppers by internal

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[2] EPN 300 insecticide. A wettable powder containing 25 per cent ethyl p-nitrophenyl thionobenzenephosphate.

Table 1.—Grasshopper toxins: a comparison of the stomach and contact toxicity of five different materials.

Materials and Concentration		Type of Action	Per Cent Mortality			Per Cent Effective Control
			8	24	96	
			Hours			
Dieldrin	0.03	Stomach	17	83	100	100
	0.25	Stomach	7	63	100	100
	0.25	Contact	0	10	80	75
	0.5	Contact	0	30	100	100
	1.0	Contact	5	80	100	100
Aldrin	0.03	Stomach	6	87	100	100
	0.25	Stomach	17	56	100	100
	0.25	Contact	0	15	40	25
	0.5	Contact	0	25	95	95
	1.0	Contact	0	45	100	100
Heptachlor	0.03	Stomach	0	34	74	55
	0.25	Stomach	4	41	100	100
	0.25	Contact	0	5	50	38
	0.5	Contact	0	30	75	75
	1.0	Contact	0	50	100	100
	1.0	Stomach	14	55	100	100
TM-1	0.03	Stomach	13	44	78	59
	0.25	Stomach	49	82	100	100
	0.25	Contact	0	5	30	13
	0.5	Contact	0	65	75	75
	1.0	Contact	10	90	95	94
	1.0	Stomach	61	93	100	100
TM-2	0.03	Stomach	4	29	88	79
	0.25	Stomach	24	96	100	100
	0.25	Contact	0	5	20	0
	0.5	Contact	0	0	0	0
	1.0	Contact	0	5	30	22
	1.0	Stomach	11	51	97	96

contact and fast in its action. It was less effective than dieldrin or aldrin as an external contact poison, and therefore might produce erratic results in the field. Low dilutions, not shown on table 1, suggested that this material had a short residual period. The insecticide was apparently dissipated before the grasshoppers had time to consume a lethal quantity.

TM-2[3] approached the toxicity of aldrin as an internal toxicant, but had almost no effect as an external poison at the dilutions used in this test. The degree of its effectiveness would depend upon the extent of grasshopper feeding at the time of application and would probably produce erratic results in the field.

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[3] Compound 1189 has the formula 2, 3, 3a, 4, 5, 6, 7, 7a, 8, 8-decachlore-3a, 4, 7, 7a-tetrahydro-4, 7-methanoindenel-1.

Control of the Northern Masked Chafer with Aldrin and Dieldrin

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Field tests with aldrin and dieldrin for the control of the larvae of the northern masked chafer, *Cyclocephala borealis* Arrow, were established in 1951 in the Wooster College golf course at Wooster, Ohio, where birds had torn up turf in the fall of 1950 to get at the grubs. This insect has been increasing in importance as a pest to turf in northeastern Ohio in the past two years. The injury becomes more conspicuous following the invasion of moles, skunks, and birds that tear up the loosened turf to feed upon the larvae.

Both insecticides were applied in the dust form by means of a fertilizer spreader at levels of 1, 5, 10, 20, 40, and 80 pounds of the technical material per acre. An untreated plot was included for each replicate making a total of seven treatments in each test. All treatments were replicated four times and were randomized within each block. Each plot consisted of an area 5 by 20 feet. A strip of untreated area 5 feet wide was left between blocks in both series. The insecticides remained on the surface of the soil for only a short time since a 0.54 inch of rain fell the day after the aldrin was applied and 0.14 inch fell shortly after the dieldrin application. This was followed with an 0.80 inch rainfall 8 days later.

All of the plots were sampled for grubs in June before beetle emergence had begun and again in the fall before the new generation of grubs had started their downward movement. Each sample consisted of three cores, 8 inches in diameter and 8 inches in depth, taken in a definite pattern in each plot. The results of the sampling are shown in the following table.

Results obtained in 1951 from plots treated with aldrin on March 2 and with dieldrin on March 5.

Actual Toxicant Per Acre	Aldrin		Dieldrin	
	Grubs Per Sq. Ft.		Grubs Per Sq. Ft.	
	June 4	Sept. 27	May 21	Sept. 28
1	5.0	.0	5.0	.0
5	2.3	.0	4.3	.0
10	.8	.0	3.3	.0
20	3.8	.0	3.8	.0
40	1.5	.0	1.0	.0
80	3.8	.0	.8	.0
Untreated	9.0	13.8	7.5	5.5

These data show the results obtained when the plots were sampled approximately three months and again 6 months after the application of the insecticides. The May and June counts were made upon the 1950–51 grub population or upon the larvae that were in the soil at the time the materials were applied, whereas the September counts were made on the succeeding generation or on the 1951–52 grub population.

A review of the data shows that the 1951–52 grub population was practically eliminated from all of the treated plots by the time the fall population was taken on September 27 and 28. It may be noted also that there was some reduction in the 1950–51 population as shown by the May–June population records. When the data were analyzed by the Statistic U Test (Mann & Whitney 1947) in order to find out if these differences were significant, it was found that all rates of both insecticides, except the 1 pound level of dieldrin, gave results significantly different from those of the untreated plots. Despite this fact, the results are relatively unimportant since the population was still high enough to cause damage. Furthermore, turf with populations of four to five grubs per square foot is oftentimes torn up by skunks and birds to feed upon the larvae.

The application of the insecticides apparently repelled the birds from the treated areas since no spring destruction to the turf by birds was noticed in any of the plots. However, in the untreated areas adjacent to these tests and in other parts of the golf course, considerable amount of turf was torn up by skunks and birds.

At no time during the summer of 1951 was there noticeable injury to the grass from any of the treatments.

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Occurrence of the Smartweed Borer and the European Corn Borer in Apples[1]

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There are relatively few published accounts of apple injury caused by the European corn borer; and, apparently, there are none that implicate the smartweed borer, or that deal with the numerical extent of damage done by either pest. Hodgson (1928) fully described European corn borer attacks on windfall apples; and Caffrey & Worthley (1927) indicated that penetration of such fruits by migrating larvae is a common occurrence in areas of heavy borer-population. Clark (1939) encountered no more than a single infested apple during a study of the host plants of the corn borer in New Jersey.

In 1951, an experimental program to evaluate concentrate sprays on apples was completed in a Red Delicious-Stayman planting at Bridgeville, Delaware.[3] When the fruit was being graded for insect and disease injury during early September, it was observed that borers, resembling the European corn borer, *Pyrausta nubilalis* (Hbn.), were responsible for considerable damage. This was especially apparent in the dropped apples. The character of the injury varied from straight tunnels, extending nearly through the fruits, to tortuous galleries that ruined most of all of the interior. Many of the entrances were plugged with frass, so that careful examination was necessary for their detection. Some of the borers were about full-grown, but the majority ranged from one-half to three-fourths that size. Records were kept of all apples that showed the injury described. A total of 19.5 per cent of the drops were so affected, and 0.5 per cent of the picked fruit. A few borers were found as high as 7 feet above the ground in unharvested apples.

Subsequently, five collections, comprising 130 larvae, were made from the Stayman variety, and one collection of nine larvae from a nearby Rome block—all from drops. Of the total from the Stayman apples, 90 specimens (69.2 per cent) proved to be the smartweed borer, *Pyrausta ainsliei* Heinr.; and 40 specimens (30.5 per cent), the European corn borer. Both species were represented in each of the above collections, except one which contained only smartweed borers. All larvae obtained from Rome apples were European corn borers.

Evidence that borers were migrating from recently-mowed vegetation that had formed the ground-cover, prompted a survey of the large dominant plants growing beneath the trees to detect the original hosts. Smartweed (*Polygonum pennsylvanicum* L.), lamb's quarters (*Chenopodium album* L.), pigweed (*Amaranthus hybridus* L.), panic grass (*Panicum dichotomiflorum* Michx.), and pokeweed (*Phytolacca decandra* L.) were dissected, and all larvae encountered were preserved for determination.

Table 1.—Number and percentage of smartweed and European corn borer larvae dissected from ground-cover plants in apple orchard, 1951.

Host	Smartweed Borer		European Corn Borer	
	Number	Per Cent	Number	Per Cent
Smartweed[1]	59	100	0	
Lamb's quarters	66	100	0	
Pokeweed	5	100	0	
Pigweed	11	73	4	27
Panic grass	37	88	6	12

[1] Smartweed examined October 1; other plants, October 5.

Table 1 presents the data obtained from this study. Smartweed, lamb's quarter, and pokeweed were infested exclusively with the smartweed borer. Pigweed and panic grass harbored both this species and the European corn borer; however, the former was much more abundant.

Probably, mowing the weeds and grasses in late August was the most important factor contributing in the infestation in dropped apples. The plant growth dried rapidly after being mowed, and the partially to full-grown larvae were compelled to seek either food or shelter elsewhere. Uncut vegetation under trees and the dropped apples were the only such possibilities in the orchard.

The considerable number of dead larvae discovered in their tunnels in fruits suggests that apples are unsuitable for the growth and development of these two species of borers. The entirely different diet and the high moisture content were, possibly, the most influential adverse factors responsibile for the high mortality.

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[2] Research Professor and Assistant Research Professor, Entomology, respectively.

[3] Reported in Trans. Peninsula Hort. Soc. 41, 1952.

Control of Aphids and Mites on Hops by Organic Phosphate Insecticides[1]

CHARLES C. CHOLLET[2] AND E. P. BREAKEY[3]

The residual toxicity of certain organic phosphate insecticides including CR-479,[4] E-1059,[5] E-838,[6] malathon,[7] and parathion was tested on hops as a control for the aphid, *Phorodon humuli* Shrank, and the spider mite, *Septanychus* n. sp. McGregor.

MATERIALS AND METHODS.—These tests were made in a 3-acre hop yard at Orting, Washington, in 1951. This yard was divided into 30 square plots containing 64 plants each. Five plots or replicates were used for each insecticide being tested. In addition, five control plots given no insecticide applications were used as check areas. The plots were completely randomized.

The following materials and concentrations were applied on July 18 and 19, using a power sprayer. Approximately a quart of spray was applied to each plant.

Parathion (25% wettable spray powder)	20 oz./100 gals.
CR-479 (Emulsion, 60% active)	16 oz./100 gals.
E-1059 (Emulsion 32.1% active)	20 oz./100 gals.
E-838 (Emulsion, 30.6% active)	10 oz./100 gals.
Malathon (Emulsion, 50.3% active)	20 oz./100 gals.

The aphid population had become well established. The spider mite infestation was light, though on the increase.

EXPERIMENTAL RESULTS.—Counts were made July 25, 1 week after application; August 1, 2 weeks after application; and August 16, 4 weeks after application. Ten leaves of medium size and maturity were picked at random from each plot. The aphid counts were obtained by counting all the living aphids appearing on the entire lower surface of each of the 10 leaves. The spider mite counts were obtained by focusing the binocular microscope on the lower surface of the leaf and counting all the living mites in one microscope field. The microscope was focused on an area two-thirds the distance from the tip of the leaf to the petiole. By using this method, the field where the mites were to be counted was located in approximately the same place on each leaf.

The data are summarized in table 1.

Table 1.—Control of aphids and spider mites on hops—1951.

MATERIAL	APHIDS	MITES
First Counts—July 25, 1951		
Parathion	0	2
CR-479	1	1
E-1059	0	0
E-838	0	0
Malathon	1	5
Check	599	20
Second Counts—August 1, 1951		
Parathion	0	8
CR-479	0	10
E-1059	0	0
E-838	11	5
Malathon	0	15
Check	728	43
Third Counts—August 16, 1951		
Parathion	0	31
CR-479	2	8
E-1059	0	18
E-838	2	4
Malathon	9	24
Check	2297	53

The data in the above table are largely self-explanatory. All of the insecticides tested seemed to give approximately the same control. However, in the last mite count CR-479 and E-838 seemed to be somewhat better than the others, as far as residual action is concerned, though the differences may not be significant.

[1] Scientific Paper No. 1103, Washington Agricultural Experiment Stations, Pullman. Project No. 858.

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[4] Bis (bis dimethylamino phosphonous) anhydride. CR 479, (Pestox) Pest Control Ltd., Cambridge, England.

[5] A trialkyl thiophosphate. Pittsburgh Agricultural Chemical Company.

[6] Diethoxy thiophosphoric acid ester of 7-hydroxy-4-methyl coumarin, E-838, Pittsburgh Agricultural Chemical Company.

[7] S-(1,2-dicarbethoxyethyl)0,0-dimethyl dithiophosphate Malathon, American Cyanamid Company.

The Toxicity of Aldrin, Dieldrin, and DDT to the Large Milkweed Bug[1,2]

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The toxicities of the three insecticides aldrin, dieldrin, and DDT were compared by injection into the large milkweed bug, *Oncopeltus fasciatus* (Dall).

MATERIALS AND METHODS.—The micro-injection apparatus used in this study consisted of a No. 27 gauge hypodermic needle attached to a 0.25 milliliter tuberculin syringe mounted so that its piston could be driven forward by a hand-operated micrometer screw. The micrometer screw would drive the piston of the syringe forward 0.005 of an inch for every cubic millimeter of solution dispensed. A small ratchet wheel 1.62 inches in diameter with 60 teeth filed on its periphery, was attached to the knurled sleeve of the micrometer in order to provide smaller injection volumes than could be obtained by using the finest division of the knurled sleeve. This ratchet arrangement produced audible clicks which represented calculated dosage volumes of 0.08 cubic millimeter. The dosage volumes most often used ranged between 1.36 and 1.76 cubic millimeters and were adjusted according to the average weights of the insects, so that the ratio of 2 cubic millimeters of liquid per 0.1 gram of insect body weight was maintained for all injections. This ratio was established by Heal & Menusan (1948) for the American cockroach, and by preliminary testing was found to be suitable for the large milkweed bug also.

All the insecticides dissolved readily in acetone at the concentrations used, and therefore acetone was the only solvent used for the injections. Pure acetone was used for the injection of controls. The three insecticides used were aldrin (recrystallized), dieldrin (recrystallized), and the para, para′ isomer of DDT.

The insects were reared in crockery bowls 12 inches in diameter, in an insect rearing room kept

[1] Contribution No. 579, Department of Entomology.

[2] This work was supported in part by a grant of funds from Julius Hyman and Company, Denver, Colorado.

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Table 1. Toxicity values and toxicity ratios (DDT=1) for DDT, aldrin and dieldrin, obtained by micro-injection of acetone solutions into the adult female large milkweed bug.

Insecticide	Toxicity Values				Toxicity Ratios			
	Micrograms per gram of insect				Times aldrin and dieldrin are more toxic than DDT			
	LD_{50}		LD_{95}		LD_{50}		LD_{95}	
	24 hr.	48 hr.	24 hr.	48 hr.	24 hr.	48 hr.	24 hr.	48 hr.
para, para′ DDT	31.0	11.0	1043	437	1.0	1.0	1.0	1.0
Aldrin (recrystallized)	4.5	2.4	72	43	6.9	4.6	14.5	10.2
Dieldrin (recrystallized)	6.9	3.8	61	39	4.5	2.9	17.1	11.2

between 74° and 84° F. and at approximately 50 per cent relative humidity (Worthley 1943). Variations in response of the insects to the chemicals due to sex or age were reduced by using only 9 to 11-day old female adults. The female adult bugs, after being selected from cultures of the proper age, were weighed in groups of 100. The average weight was calculated, and the dosage determined from a table prepared to give the dosage volume for any weight insect between 35 and 102 milligrams on the basis of 2.0 cubic millimeters of injection solution per 0.1 gram of insect. The insects were injected and placed in wide-mouth pint mason jars fitted with gauze covers for observation; milkweed seeds and water were placed in the observation jars. The injected insects were observed 24 and 48 hours after injection, and the number of dead and moribund individuals recorded.

Six concentrations of each chemical were used and 100 insects were injected with every concentration of each chemical in each of the three replications. Each replication had 100 insects for controls which were injected with the solvent only. The average mortality of the controls varied from 3 to 11 per cent for the period of observation. Approximately 5700 insects were injected. The six concentrations provided sufficient data for the calculation of the dosage-mortality curves. The median lethal dose (LD_{50}) and the dosage lethal to 95 per cent of the insects injected (LD_{95}) for the 24 and 48 hour observation periods were calculated from the regression equations derived from the average mortalities of the three replications.[4]

Results.—The toxicities of the three insecticides, as measured by their LD_{50} and LD_{95} values, are listed in table 1 in terms of micrograms of toxicant per gram of insect body weight. In order to afford a more direct comparison of aldrin and dieldrin with DDT, the toxicity values of these two chemicals have been converted to ratios of the toxicity values for DDT with the values for aldrin and dieldrin for the same mortality level and observation period. In table 1, these toxicity ratios are listed with a value of 1 for DDT; the toxicity ratios for aldrin and dieldrin represent therefore, the number of times these chemicals were more toxic than DDT under the conditions of this experiment.

Discussion.—A comparison of the LD_{50} values of the three chemicals, shows a descending order of toxicity for aldrin, dieldrin, and DDT, but this order of descending toxicity is reversed for aldrin and dieldrin in the case of the LD_{95} toxicity values; in this latter case, the toxicity decreases in the following order: dieldrin, aldrin, and DDT. Kearns *et al.* (1949) report LD_{50} values by topical application on adult female milkweed bugs, 96 hours after treatment, of 10.3 ± 7.5 micrograms of aldrin per gram of bug and 15.0 ± 5.0 micrograms of dieldrin per gram of bug. The lower toxicity values for aldrin and dieldrin reported in this present paper are possibly the result, in part at least, of the introduction of the chemicals into the coelomic tissues of the insect body.

Summary.—A comparison of the toxicity of aldrin (recrystallized), dieldrin (recrystallized), and para, para′ DDT was made by injecting acetone solutions of these chemicals into the coelomic tissues of adult female large milkweed bugs. The toxicity values were calculated from the regression equations which were derived from the average mortalities of three replications involving approximately 5700 bugs. The toxicity of aldrin ranged from approximately 5 to 15 times the toxicity of DDT and the toxicity of dieldrin ranged from approximately 3 to 17 times the toxicity of DDT under the conditions of this experiment.

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Kearns, C. W., Carl J. Weinman and George C. Decker, 1949. Insecticidal properties of some new chlorinated organic compounds. Jour. Econ. Ent. *42*(1): 127–34.

Worthley, Harlan N., 1943. Laboratory Procedures in Studies of the Chemical Control of Insects. A. A. A. S., Publ. No. *20*: 31–3.

[4] Statistical analyses and interpretations were made under the direction of H. C. Fryer, Kansas Agricultural Experiment Station Statistician.

NOTES

United States Department of Agriculture

Office of Personnel

Washington, February 14, 1952

Agricultural Specialists Needed for Near East and Southern Asia:

A large number of specialists in certain agricultural fields are needed to represent the United States in technical cooperation programs abroad, especially in the Near East and Southern Asia, the U. S. Department of Agriculture announced today. The greatest needs are for extension and agricultural education specialists. There also are a number of positions for specialists in agricultural engineering, animal husbandry, entomology, plant pathology, horticulture, soils and agronomy.

About 500 United States agricultural technicians now are doing technical cooperation work abroad, under programs of this Government and the United Nations. The Department's Office of Personnel has developed a national roster of professional agriculturists that is being used by the Department and other agencies in recruiting such personnel. Specialists have been recruited rapidly enough to fill most current staff needs for some geographic areas and in certain subject matter fields. However, expanding program requirements in the Near East and Asia now make it necessary to enlarge the roster of qualified applicants in the technical fields listed above. Especially needed to work in the field of extension are candidates experienced as county agents or as vocational agriculture teachers.

This country's technical cooperation programs, which include Point Four, require professionally trained people of proven ability. These employees must have had several years of successful professional experience and must be skilled in their professions. They must have leadership ability, maturity of judgment, and the perslnal quaoities required of foreign representatives of the United States Government.

Applicants are not required to take Civil Service examinations. However, applicants must meet high qualification standards established for these positions. Candidates preferably should be between 30 and 60 years old. Salary rates range from $5,913 to $11,130 a year. In addition, employees may receive quarters and living allowances, and in some cases post differential allowances of from 10 to 25 per cent of the base salary.

Interested persons who are qualified by training and by several years of responsible professional experience in agriculture are asked to submit Form 57, Application for Federal Employment, or write to the Office of Personnel, U. S. Department of Agriculture, Washington 25, D. C. Form 57 may be obtained from First and Second-Class Post Offices.

The Third International Congress of Phytopharmacy will be held in Paris from September 15 to September 21, 1952, at the Sorbonne. Address the IIIéme Congres International de Phytopharmacy, 57, Bd. Lannes, Paris (16éme) France.

Eleventh Annual Meeting Northwest Vegetable Insect Conference

The eleventh annual meeting of the Northwest Vegetable Insect Conference was held at the Imperial Hotel, Portland, Oregon, on January 21, 22, and 23, 1952. The membership is comprised of state, federal, and dominion Entomologists engaged in research or extension work pertaining to insects of vegetable and related crops in Oregon, Washington, Idaho, Montana, Utah, British Columbia and Alberta. Representatives from California and the Bureau of Entomology and Plant Quarantine, Washington D. C., were also in attendance.

H. S. Telford was chairman, and H. E. Morrison, co-chairman of the Conference. January 21 and 22 were closed sessions and January 23 was an open session to members of industry. Discussion leaders were Harry Fulton for insects of crucifers, carrots, lettuce, asparagus, corn, celery, and onions; Howard E. Dorst for insects of beets, tomatoes, beans, and hops; A. J. Walz for insects of potatoes; W. C. Cook for insects of peas; H. H. Crowell for wireworms, symphilids, etc. and effect of soil inecticides on plants and soil organisms; and E. P. Breakey for insects of small fruits, berries, and ornamentals.

On the morning of January 23 a progress report on research work for 1951 was presented to members of industry at the open session. Abstracts of Research were prepared and distributed with the compliments of the Western Agricultural Chemical Association.

Members of the Executive Committee for 1953 are C. L. Neilson, Provincial Entomologist, Vernon B. C., *Chairman;* Loyd L. Stitt, Entomologist, Western Washington Experiment Station, Puyallup, Washington and David H. Brannon, Extension Entomology Specialist, State College of Washington, Pullman, Washington, *Secretary.*

The 1953 Conference will be held on January 19, 20, and 21 at the Imperial Hotel, Portland, Oregon.

The following persons registered for the closed sessions:

Loyd L. Stitt	John C. Elmore
Paul M. Eide	Ralph Schopp
B. J. Landis	J. H. Newton
E. C. Klostermeyer	H. H. Hessig
H. H. Crowell	H. C. Manis
E. P. Breakey	R. W. Portman
C. R. Amen	W. C. Cook
Don Berry	J. R. Douglass
Robert W. Every	Andrew Steiner
M. C. Lane	H. J. Shipman
Harry Andison	Howard E. Dorst
Arthur J. Walz	Howard F. Madsen
L. B. Reed	L. G. Gentner
C. L. Neilson	D. W. Dean
R. H. Handford	H. E. Morrison
H. G. Fulton	R. G. Rosenstiel
David H. Brannon	A. J. Culver, Jr.
H. S. Telford	John A. Davis
C. W. Getzendaner	D. J. Crowley

CHANGES IN CONNECTICUT

Mr. Neely Turner has been appointed Head of the Department of Entomology of The Connecticut Agricultural Experiment Station and State Entomologist of Connecticut as of January 1, 1952.

Roger B. Friend will continue on the staff of The Connecticut Agricultural Experiment Station, devoting his time to research problems.

ENTOMOLOGISTS TO KOREA

Three entomologists, namely Mr. Gaines W. Eddy, Dr. Carroll Smith, and Mr. Irwin Gilbert of the Division of Insects Affecting Man and Animals, Bureau of Entomology and Plant Quarantine, left in June, 1951 for Korea to work in cooperation with the military services in evaluating insecticides for the control of insects of medical importance.

Howard Beauchamp Owens, Greenbelt, Maryland, was honored on March 20 by the Washington Academy of Sciences for outstanding achievement in the teaching of science during 1951. Mr. Owens is a graduate of Washington College; received his master's degree at the University of Maryland in 1944 and is now engaged in graduate studies leading to the degree of Ph.D. The work for which he was cited is in connection with the training of the winner of the Science Talent Search, Miss Martin. He has initiated science fairs in the high schools of Prince George's County and this idea has spread throughout the nation. Mr. Owens has been a teacher of science for many years and is now teaching in the Northwestern High School.

Dr. W. A. Baker, of the Bureau of Entomology and Plant Quarantine has sent out a notice to the effect that Mr. E. W. Beck will be acting in charge of the European corn borer research program of the Bureau which is located with headquarters at Ankeny, Iowa.

Mr. W. G. Bradley, presently in charge, is to undertake work on the Point IV Program in the Dominican Republic in the immediate future and Mr. Beck assumes his duties at Ankeny at once.

EDITORIAL

Some Fundamental Problems Characteristic of Large-Scale Pest Control Projects

With new insecticides, new methods of applying them, and the incentive created by a steadily increasing demand for greater farm production and better-quality products, entomologists are emphasizing a new approach to pest control. This approach promises safer, more efficient, and more economical protection from many of our major insect pests. Problems associated with contamination of food, plant and animal tolerances, residues in soil, availability of materials, and manpower all point to "*preventive entomology.*" It never has been so important before to know how, when, and what to use to do an efficient job of pest control with the least expenditure of manpower, chemicals, and machinery.

Large-scale pest control often has meant fighting insects or diseases on a "sandbag" basis. We don't ordinarily build a dam at the crest of the flood. It may prove expedient to sandbag the levees as an emergency measure, however, when the water reaches flood stages. "Sandbag control" of crop pests is a stopgap only, whether practiced by the farmer or conducted as a jointly financed federal, state, and farmer program, and leaves little of a permanent or constructive nature once the flood has subsided. To prevent widespread and destructive outbreaks of crop, forest, and livestock pests from occurring periodically, there must be foresight, intelligent planning, and scientific and constructive building when "the water is low." A background of experience and training must go into the selection of the time and place for effective action and into the plan for a permanent structure; *and* there must be money spent in building at a time when there is little threat of damage, otherwise talent and materials will not be used most effectively.

It seems to me that a striking analogy may be drawn between sandbagging the levees when water is high and some of the so-called large-scale programs for pest control with which you are familiar. One of the oldest and most widely publicized of these is the gypsy moth control program.

For some 50 years gypsy moth control was a fine illustration of sandbag control. In spite of joint federal and state effort the pest was steadily spreading to the west and south. Fortunately, in this case, new procedures became available and the balance of power reversed. It is believed now that the gypsy moth has been exterminated from some 400 square miles in Pennsylvania, as it was from an area of comparable size in New Jersey. New York State expects within a few years to have driven it back beyond the Hudson River. Experiences of the past few years strongly suggest that the gypsy moth can be eliminated from this country. But millions of dollars will have to be expended if this is done to accomplish an objective first recognized and advocated some 50 years ago.

Let us have a look at another forest pest which you have heard much about in the last 2 or 3 years—the Englemann spruce beetle in Colorado. This beetle is a native insect. The insect does little economic damage under normal circumstances. It is practically impossible, however, to draw a work picture of its potential destructiveness. More than 4.5 billion board feet of spruce have been destroyed in Colorado since about 1938 or 1939, when a severe storm blew down or weakened a sufficient number of trees to create conditions ideal for the insect to multiply, and to overcome the natural forces that normally hold the pest in check. This outbreak gained momentum rapidly because of the inaccessibility of the area where the blowdown occurred and the lack of know-how and practical facilities for immediately undertaking artificial control. By 1949 an estimated 800,000 trees were infested. The epidemic had swept over approximately a quarter of the merchantable spruce in the state. The magnitude and intensity of the outbreak can not be comprehended without a visit to the area. There are thousands of acres of spruce without a living tree, pole size or larger. At least another one-third of the spruce in Colorado is in the path of the flood.

In a similar manner we have watched

the tussock moth in Idaho develop from an infestation involving a few thousand acres in 1944 to a situation where some 400,000 acres required treatment to suppress the outbreak. An epidemic of the spruce budworm in the white and Douglas fir areas of Oregon will require the treatment of at least 2 million acres before a biological balance is restored between the budworm and its parasites and predators.

Grasshoppers and Mormon crickets until very recently were fought on a sandbag basis. The work of J. R. Parker and others who have studied the ecological factors influencing grasshopper populations and methods for their control have shown that outbreaks of considerable magnitude occur nearly every year somewhere west of the Mississippi River, with widespread outbreaks of regional or national significance about every 10 years.

It is almost impossible to arrive at a reasonable estimate of the damage that grasshoppers and Mormon crickets have done to western agriculture. Farmers until recently were accustomed to accepting periodic invasions as inevitable. Losses of 5 to 10 per cent, both in cultivated crops and on grasslands, were common. In fact, grasshopper damage was expected and accepted over wide areas in the West—much the same as drouth, hail, or other uncontrollable elements. However as Claude Wakeland has pointed out "grasshopper control procedures have undergone more evolution in the past 5 years than during the preceding 60."

Many workers closely associated with the problem of grasshopper control are optimistic that these most destructive of all crop pests can be combatted on a preventive basis. However, good results depend on constructive thinking and—then acting when infestations are low. There must be carefully planned and coordinated surveys, organized and directed by men with training, experience, and vision, who can determine the "site," and then construct the "dam." It is important that we take full advantage of all the technical knowledge that can be brought to bear on the problem. It takes time, money, and perseverance to do this—when nature is helping rather than hindering. The "dam" must be constructed when the water is low.

Let us turn for a moment to the case of white pine blister rust. The fungus causing this killer of our most valuable forest species was introduced from Europe on nursery stock about 1900. A second introduction on the West Coast occurred at Vancouver, British Columbia, about 1910 but was not discovered until 1921. To thrive and spread, the blister rust fungus had to find certain species of ribes growing in association with white pines. It encountered these conditions plus a climate and other ecological conditions much to its liking. Without adequate knowledge or facilities for combatting the disease when it was first discovered, the river of infection soon reached flood stages. Another sandbag operation was on our hands. It is needless to say that the levee broke.

Blister rust now occurs throughout the natural range of both eastern and western white pines. It has invaded the sugar pine areas of California and extends into the Appalachians. Sufficient time has now elapsed to prove beyond doubt that if the eradication of *Ribes* had not been undertaken and vigorously pursued white pines would in time have suffered a fate similar to our chestnuts.

Fortunately, in the case of this disease it is possible to select and protect the more productive white pine stands of the country at a cost well within the economics of this important crop. It has become evident, also, that only in protected areas will we grow another crop of white pine as existing stands mature and are harvested. There are now some 6 to 7 million acres of white pine in the United States protected from the blister rust disease. If we are to continue to utilize this important wood at the present rate, it will be necessary to protect areas totaling 25 to 28 million acres. Otherwise this valuable lumber will not be available in amounts adequate for its many specialized uses.

Large-scale pest control may have any one of several objectives. For introduced pests, it may be an effort to eradicate an incipient infestation. Short of eradication, organized suppressive work may be conducted as a delaying action—buying time for much needed research to determine more effective, economical, and safer control procedures. When native insects are involved, it may be a matter of organizing an areawide control effort to meet an emergency that can not be successfully combatted by individuals working inde-

pendently, as in the case of migratory species of grasshoppers, or it may be an attempt to suppress an outbreak of forest insects threatening destruction of valuable timber resources requiring a hundred years or more to replace.

Likewise, large-scale pest-control programs fall into two broad categories: (1), Those that are carried out by farmers or individual property owners as a regular part of their farming operation, and (2), those that require an areawide or regional approach and warrant the use of public funds. In either case there is much to be gained by a preventive approach.

A critical appraisal of organized and publicly supported pest-control operations reveals certain fundamental problems characteristic of nearly all of them. Usually control effort has been delayed until the pest has demonstrated its destructiveness, which in the case of new introductions often has meant firm establishment over sizable areas. In such cases technical information on which to plan an intelligent and effective program of eradication or control usually has been lacking. Knowledge has been completely inadequate in many instances as to host range, the influence of environment, natural enemies, and the destructive potential of the pest under conditions and cropping practices that prevail in this country. Delimiting areas of infestation often has been difficult. At times there has been lack of uniformity in the thinking of technical people as to whether or not organized effort was justified, and much critical time has been lost while these differences were resolved. For lack of flexibility in organization and facilities, and the popular support essential to undertake work on a preventive basis, we, both federal and state, have been slow to marshal our forces into a balanced and coordinated program of investigation, quarantine, and control. Where cultural practices and biological control have failed, several years of research have been required to develop insecticidal treatments to a point that an aggressive program of suppression could be undertaken.

There is urgent need, in my opinion, for greater flexibility in the use of personnel and facilities in our research programs. When situations arise warranting organized preventive action, there should be opportunity for prompt redirection and expansion of our investigational forces. If regulatory and control work becomes a part of the program it must be *aggressively supported* by research. In my opinion the productiveness of organized and publicly supported pest-control work could be substantially increased by having the following:

(1) An organization, with facilities, that permit an alert and aggressive research program without the usual delays or interruptions occasioned by the lack of legal authority or finances essential to prompt action.

(2) An adequately staffed, trained, and flexible foreign plant quarantine service to function as our first line of defense against potentially destructive pests as yet not established in this country. This is about the cheapest insurance we can buy.

Unfortunately, you hear little about the thousands of interceptions that inspectors of this service make annually. You *do* hear a lot about pests that penetrate this first line of defense and in time establish a bridgehead somewhere in this country. Included in this group are the European corn borer, the Japanese beetle, the white-fringed beetle, the pink bollworm of cotton, and the Mexican bean beetle.

Each of these pests has saddled, or has threatened to saddle American agriculture with greater production costs. American farmers already spend an estimated $70,000,000 annually for insecticides. Add to this the cost of application and the value of the crops destroyed in spite of this effort, and you have a fair appraisal of what *bugs* mean to the agricultural economy of this country.

(3) A joint Federal-State survey organization of highly trained, alert, practical technicians directing its efforts toward sound preventive programs of pest control rather than "sandbagging" the levees after the destructive forces of nature are out of hand.

(4) There is in my opinion an urgent need for strengthening that phase of entomological service which provides for pilot-plant testing of new procedures. We must be sure that our recommendations are effective and practical, and that they take into consideration the welfare of the operator and the protection of the consumer against toxic residues. Pest control must be accomplished without im-

pairing the immediate or future productivity of the soil.

Entomologists, pathologists, and insecticidal chemists are constantly confronted with the matter of residues—residues on the commodities moving to market and in the soils where these commodities are grown.

Nowhere in the world are pesticides used so generally and in such quantity as in the United States. Few people appreciate to what extent sound crop-pest control contributes to the high yields, stability of production, and the high quality of the products produced on our farms. The time has come when few crops can be grown successfully in this country without some artificial protection from insects and diseases. But along with information as to how best to control crop pests has come a fuller appreciation of the responsibilities that rest on those who recommend the use of the many toxic materials that are now common ingredients of our more effective treatments. In addition to discovering or formulating a new insecticide, the entomologist, the chemist and the agricultural engineer must find ways to use it safely. They must find ways to avoid deleterious residues on foods, ways to avoid off-flavors in foods grown on treated soils, and ways to avoid hazardous accumulations in the soil. In a highly specialized agricultural economy such as ours, problems associated in one way or another with residues in soils will undoubtedly become more acute as time passes. In short, what price might we pay tomorrow for controls we fail to apply today?

Sound pest-control practices are so closely interrelated with crop, forest, animal, and even household management, that in the pilot-plant stage of the development of control procedures entomologists, plant pathologists, chemists, and others concerned with the more exacting sciences associated with production, transportation, and storage of agricultural commodities must be informed of management's plans and trends. They will then know that the recommendations made are not in conflict with sound or prevailing practices, or that management's plans are modified so as to be compatible with sound pest-control procedures. There are many occasions when entomologists, pathologists, chemists, and agricultural engineers must recognize and assume some share of responsibility in the development of recommended farming or forestry practices, if such recommendations are to be balanced scientifically.

Looking toward the future, perhaps a few examples will serve to indicate what seems to be a definite and highly significant trend in the current thinking of economic entomologists. J. R. Parker and his associates had demonstrated on experimental plots a few fundamentals by 1947, destined to revolutionize our approach to grasshopper control. They learned that (1) 8 to 16 ounches of chlordane or 1 to 2 pounds of toxaphene applied directly to vegetation on which grasshoppers were feeding gave better control than bait under most conditions, (2) these materials could be applied to fence rows, roadsides, field margins, and other breeding ground as mist sprays, with either airplanes or ground equipment, and (3) when applied as finely atomized sprays adequate coverage was obtained with as little as 1 to 2 gallons per acre. These workers had advocated properly timed community-wide effort for best results for a long time.

In 1947, with the cooperation of the State of South Dakota and a group of progressive farmers, the knowledge secured from these experimental plots was subjected to the pilot-plant test in an area comprising some 25,000 acres of intermingled crop and grasslands. The object was to establish whether or not grasshoppers could be satisfactorily controlled by well-timed treatments of only those parts of the fields, field margins, fence rows, and roadsides where hatching would occur—a strictly preventive approach which if successful, would accomplish a high degree of control with a minimum expenditure of time and materials, without creating a residue problem, and in time to avoid any measurable amount of damage. This and programs of a similar character, repeated during the past four seasons in Nebraska, Kansas, and North Dakota, have demonstrated that under most conditions, farmers now have facilities to protect their crops from grasshoppers without the cost becoming burdensome. It is *assumed*, of course, that the crops are not exposed to invasion by grasshoppers breeding at some distant point. The situation has become even

more encouraging by the availability of aldrin. This insecticide promises excellent control of all species over a wide range of ecological conditions, when applied in quantities of only 1.5 to 2 ounces per acre, in a gallon of oil emulsion or as an oil solution.

In a community-wide experiment involving some 3000 acres of cotton, K. P. Ewing and his associates demonstrated a revolutionary approach to the control of the cotton boll weevil in the Waco, Texas, area. In 1950 treatments in the experimental areas were limited to three early sprays. No mid- or late-season applications were made. In spite of heavy weevil emergence and favorable conditions for their development, the infestations on the crops so treated remained extremely low throughout the growing season; 8 per cent of weevil-punctured squares as compared with 38 per cent in the untreated checks. The grade and yield of lint from the treated crops was higher than that from the check fields, 474 pounds per acre as compared with 270 pounds, a gain of 76 per cent. It was calculated that the net returns on the farms so treated were increased by almost seventy-five dollars an acre. In addition, the cotton reached maturity 2 to 3 weeks ahead of untreated cotton, due at least in part to the control of associated cotton insects.

You are all more or less familiar with the cooperative work undertaken in Mexico to prevent or retard the northward spread or retard the northward spread of the citrus black fly, and in Hawaii with the oriental fruit fly, which threatens to become a major problem over wide areas should it become established in this country. If we are not successful in preventing these highly destructive pests from establishing a bridgehead in this country, we will at least know something about them when they get here—something about their life histories, what hosts they attack, what help to expect from parasites and predators, and what artificial controls may be used with safety and effectiveness.

These examples seem to me to illustrate rather convincingly the trend that entomology is now taking. Undoubtedly this trend can be accelerated—become more positive as we gain fruther experience with the new procedures and the many new materials now under test. Only by exploiting such trends can we hope to establish large-scale pest control on a preventive basis—thus protecting ourselves from a constantly increasing demand for combatting "floods" at a tremendous expenditure of needless effort, time and money.

It is doubly important in this time of national emergency that we utilize our knowledge, manpower, chemicals, and machinery devoted to crop pest control to the fullest possible extent. To gain this objective there must be joint planning and close integration of the efforts of federal and state technicians and the many private industries having an interest and responsibility in this important field. Reducing insect damage by 50 per cent, which is not an unreasonable goal, should go a long way toward solving some of the more acute production problems facing the country at this time.

W. L. POPHAM, *Assistant Chief, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.*

BOOK NOTICES

FILTH-INHABITING FLIES OF GUAM, by George E. Bohart and J. Linsley Gressitt. Bernice P. Bishop Museum, Honolulu, Hawaii. 1951. 152 pp., 17 plates. Paper bound.

It is the hope of the authors of this fine publication that their presentation "will be useful as a handbook on fly problems of Guam and serve as a general guide for studies of fly-breeding problems in other Pacific areas. Persons in areas other than the Marianas should be able, with due caution, to make use of the keys and drawings for identification of the various stages of many genera and some of the widely distributed Pacific species." It is likely their hope will be realized.

The economic and public health importance of flies commonly associated with filth need not be elaborated here. In addition to considering this part of the filth-inhabiting fly problem, Bohart & Gressitt have ably treated all other major aspects of the subject. Included, for example, are data and records relating to: the geographical zones of Guam (in relation to fly populations), field observations and collecting, the morphology and biology of the flies, habitat studies, taxonomic studies, the relation of flies to disease, food habits, natural enemies, control problems, and others. Among the conclusions arrived at through their study the authors report that *Chrysomya megacephala* (Fabr.) and *Musca sorbens* Wied. are medically the most important filth flies on Guam and probably on other Pacific islands.

The greater part of the publication is concerned with the taxonomy of the filth-inhabiting flies of Guam. An extensive key for the separation of species in all stages is included. Information concerning the species and higher categories of the flies is summarized on 79 pages. The 17 halftone plates are clear and well-done. A bibliography and index round out what constitutes a distinct contribution to the knowledge of the Diptera of Guam.

LIST OF PARASITES OF DOMESTICATED ANIMALS OF NORTH AMERICA, by Edward A. Benbrook. Second edition. Burgess Publishing Co., Minneapolis, Minnesota, 1952. $8\frac{1}{2}\times10\frac{3}{4}$ in. Spiral binding. iii+63 pp.

This list is intended to supplement a course in veterinary parasitology and includes parasites of fourteen vertebrate hosts reported from continental North America nosth of Mexico arranged according to body systems. Common names, size, and major category to which the parasites belong are given. Authors of scientific names are omitted. There is no bibliography, and sources of records are stated only in a few instances.—WILLIAM E. BICKLEY.